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THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS.*

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Before entering upon such considerations as affect the selection of reservoir sites and their construction, a brief allusion to some of the most ancient works for impounding water may not be uninteresting. Of these the most prominent examples are undoubtedly to be found in Hindostan, where the magnitude and antiquity of the storage works cannot fail to arrest attention. These great works, surpassing in their immensity what are conventionally esteemed to be the wonders of the world, the production of other countries and nations, took their origin in the necessities of the people and the variableness of the climate of India, and were, in fact, great public works on which the welfare of the people mainly depended. The climate of India, although singularly uniform in some respects from year to year, is remarkably variable as regards the rainfall; and in order to guard against the disasters of famine and sickness, inevitably attendant on a scanty monsoon, the native princes were wont to make such provisions as large resources and an almost unlimited power enabled them, in order to obviate the difficulty that they had to contend with.

The rain records of India for several years past show that a scarcity of rain is indicated by periods of about five years, or that every fifth or sixth year is marked by a scanty rainfall over certain districts. The recurrence of these periods is, of course, not very clearly marked, but still it is sufficiently so to warrant, with approximate correctness, the prediction of scarcity and famine; and such deplorable recurrence is, as all are aware, now reigning in India, and visiting with destruction, by sickness and hunger, some thousands whose sole dependence is upon a fair season of rain, and the successful maturing of their little crop of grain.

The natural expedient for guarding against the recurrence of these periodical calamities was evidently to be found in husbanding a scanty supply of rain-water for the purpose of irrigation, and this the people of India appear to have understood. They took advantage, in certain districts, of every nook and ravine, whether large or small, and converted them into storage reservoirs by throwing across banks of earth, or bunds, as they are termed, producing, in certain districts, such an elaborate and complete system of irrigation as can only be compared, for cost and completeness, to our railway system in England. Taking fourteen districts in the Madras Presidency, where tank irrigation was most generally relied upon, the records of the Indian Government show that there are no less than 43,000 irrigation reservoirs now in effective operation, and as many as 10,000 more that have fallen into disuse, making a total number of 53,000 storage works. The ave-

*A Paper read before the Society of Engineers.

rage length of embankment is found to be about half a mile, the extreme limit of the series being a dam of the immense length of 30 miles. This ancient reservoir, called the Poniary tank, is no longer in use, the cost of maintaining such a length of bank in adequate repair having probably been found disproportionate to the advantage derived from the supply. The work, embracing an area of storage of between 60 and 80 sq. miles, remains however as a record of what the Hindoos are capable of. To quote a second example, there is the Veranum reservoir, now in actual operation as a source of supply, and yielding a net revenue of no less than £11,450 per annum. The area of the tank is 35 sq. miles, and the storage is effected by a dam of 12 miles in length. In order to bring the immensity of this system of storage works within the reach of statistical minds, it has been calculated that the embankments contain as much earth as would serve to encircle the globe with a belt of 6 ft. in thickness. To show that these are not singular examples, one other embankment of remarkable size may be alluded to. This embankment, of somewhat singular construction, was built on the island of Ceylon, and bears testimony that the Singalese monarchs were not behind their neighbors in public spirit or enterprise. The embankment was composed of huge blocks of stone strongly cemented together, and covered over with turf, a solid barrier of 15 miles in length, 100 ft. wide at base, sloping to a top width of 40 ft., and extending across the lower end of a spacious valley.

Thus it will appear that the practice of embanking across valleys, for the purpose of retaining the surface water, has for ages been in operation. There is no doubt that the disposal of some of the most remarkable works in India is not what it might, with advantage, have been; the fact remains, however, that the desired end was attained, and if the earthworks were disproportionately extensive, it was a source of satisfaction at least for the projectors to know that they cost, as a general rule, little or nothing, the practice in those days being to press whatever labor was required, rendering in return nominal wages or none at all.

The two main questions that it is proposed to submit for consideration are, first, the selection of a reservoir site; and, secondly, the leading principles to be observed in the designing and construction of storage works.

The purpose or purposes for which the work may be required will, of course, affect materially the choice of a position, as well as the details of the structure itself; but certain general principles are available for our guidance in every case, after considering which, it is proposed to dwell upon such points as apply to the special purposes for which reservoirs may be constructed.

The first and most essential point for accurate determination by the engineer is undoubtedly the amount of rainfall, both maximum and minimum, that may be expected in the district under examination; and, having arrived at reliable data on this point, the next consideration will obviously be, what amount may be made available, due allowance having been made for evaporation and absorption. When we know that the annual depth of rainfall taken all over the world varies, according to the locality, between zero and 338 in. or 28 ft. deep (which excessive amount was on one occasion registered in the hill district of Western India), it will be obvious how little ground there will be for assumption, in the examination of any district hitherto unexplored, with regard to the question of its rainfall. In the examination of any given country, however, there are certain phenomena connected with the rainfall that will be found of almost invariable acceptation, and may with advantage be borne in mind.

The rainfall will, as a general rule, be greatest in those districts that are situated towards the point from which the prevailing winds blow. If Great Britain for instance be taken, the western districts will be found the most rainy. The very reverse, however, of this phenomenon is noticed in the neighborhood of mountain ranges. If the wind prevails from one side rather than from the other, it is found that the greatest rainfall is on the leeward side of the range, and the probable solution of the matter is, that the air, highly charged with moisture, is carried up the hills by the wind until it comes into a cold region of the atmosphere. Condensation of the watery vapor immediately takes place, and the result is a fall of rain on the side of the mountain range remote from the prevailing wind.

To this cause may also be attributed the fact that the rainfall is always greatest in mountainous districts, while it by no means

follows that elevated plains are more abundantly supplied with rain than land lying nearer to the sea level. The principles are remarkably exemplified in the southern part of the Bombay Presidency, where the author has had occasion to study the subject of rainfall. The Western Ghauts run parallel to the coast, rising to a height of 4,500 ft. above the sea, and form the western support of the great table-land of the Deccan, the mean elevation of which may be taken at 3,000 ft. In the rainy season the south-west monsoon, blowing from the sea, impinges against the ghauts, and while passing onwards to the Deccan, parts with its moisture to the average annual amount of 254 in. On a spur of mountain that runs eastward, the pluviometers are found to register but 50 in.; and about 40 miles farther inland the rainfall is not more in some places than 15 in., which is considerably less than that registered in the lower-lying districts of the Presidency.

In civilized countries like our own much valuable information is as usually available regarding the rainfall, if not applying actually to the district under examination, then probably to some neighboring districts, enjoying the same physical characteristics; but when any project of great importance is in contemplation, it will not be sufficient to take the returns of adjoining districts as accurate information of the rainfall at the exact locality fixed upon for the construction of the works. It will be necessary to establish rain-gauges at different points over the catchment basin of the valley from which it is intended to obtain the supply; and daily observations of these gauges must be taken for comparison with a series of simultaneous observations taken and recorded at the nearest station at which the rainfall has been regularly and carefully noted. It is evident that a comparison of the several observations taken over the area of water-shed with those registered at the permanent station, will convey a just estimate of the amount of maximum and minimum rainfall that may be relied upon.

The amount of rain falling upon the ground is not, however, the point to be determined, though it will aid considerably as a guide to the engineer. A considerable quantity of all the rainfall is either absorbed by the ground or evaporated before it reaches the point at which it can be made available for storage. Regarding, then, first the question of absorption, it must be apparent that no two districts, unless they are exactly identical in soil, inclination of surface, and under similar circumstances of cultivation, can give on examination the same comparative result of rainfall and evaporation. If one district or unit of area be similar to the other in all respects but the surface inclination, that which has the greatest slope will, as a rule, give the largest percentage of water available for storage, because of course there will be less time for the rain to be absorbed. Again, the degree of cultivation will materially affect the result when two areas, otherwise precisely similar in their physical conformation, come to be compared one with the other, it being evident that an open and well-drained soil will be more favorable to the retention of water falling upon it than compact and impervious land. In every case the physical features of a district will each and every one of them force itself on the attention, as influencing the conclusion to be arrived at. If any general rule can be applied, it may be said that the greater the slope of the valley, the more rapidly it will throw surface water off; the more denuded the surface is of soil of any kind, the less will the escape of rain-water be retarded; and the more compact the rocks composing the geological structure of a district, the better will the circumstances be for impounding water. The volcanic rocks and those of the granite order will be as favorable as any that could be desired; while, on the other hand, porous rocks, such as the sandstones, chalk, etc., are too absorbent to offer the desired conditions for storage. It is not here asserted that all the water absorbed by porous rocks is necessarily intercepted from passing away to contribute to storage supply; much of it may be lost by evaporation and absorption by vegetables, but a considerable portion will often be found to contribute in the form of springs, if the disposition of the strata be favorable.

As a further source of loss, evaporation from the ground as well as from the surface of the reservoir, must be taken into consideration. The circumstances attending the latter source of loss will be considered further on, as this does not affect the question of how much of the total rainfall may be made available.

The question how much water will be evaporated at any moment from the surface

of land is one involved in considerable difficulty; and so many disturbing elements enter into the solution of the problem, that its accurate determination may be regarded as hardly possible of attainment. The hygrometric state of the ground's surface, the aspect of the sky, the amount of wind, and the temperature, will all, in their degree, exercise a sensible influence on the amount of water that the ground will give off from its surface; so that, in fact, it is doubtful whether any reliable and philosophically correct conclusions can be arrived at. The resultant facts from such experiments as have been carefully conducted afford, after all, the only data for the engineer to arrive at any general conclusion by; and for forming a rough estimate for the probable available rainfall of a district, the following proportions of available actual rainfall may be accepted as furnishing general data; but they are not meant to obviate the necessity of a careful and specific examination of the circumstances likely to affect the design of any particular work :

Steep surfaces of granite, gneiss, and slate	100
Moorland and hill pasture	60 to 80
Flat cultivated country	40 to 50
Chalk	0 to 0

In order to arrive at more specific, and truly reliable results, the engineer will have to make a series of accurate observations on the discharge of the stream or streams that carry away the rainfall of a district; and by doing so, and at the same time comparing the result with the amount of rain registered by the gauges—which should also, of course, be kept with accuracy in the locality under examination—an approximately true estimate of the available rainfall will be arrived at.

If there is time in the preparation of a project to make the necessary examination of a district, it is evident that the results will speak for themselves; and there will be no necessity to enter into abstract speculations concerning the theory of the influences affecting loss by either evaporation or absorption.

In proportioning the size of a storage reservoir to the area of the catchment basin, the engineer will, of course, in the first instance be guided by the requirements of the work. The object of the undertaking may be any one of the following :

To husband a scanty rainfall.

To check the injurious effect upon the country by floods.

To add to the discharge of a stream, by preventing the escape of the flood waters.

The amount of storage will always be part of an engineer's data in designing works. It will either be his object to store the whole of the water that the drainage area will afford, which will be the case in impounding water for irrigation, for example; or a certain fixed demand, governed by the want of a town or other requirements, will determine the amount of the rainfall that it will be necessary to retain for supply. In England the demand for water supply may be reckoned at from 150 to 180 days, depending on the amount and the constancy of the rainfall; as a rule, the six months' supply will be the safest to adopt. The following Table, extracted from Mr. Beardmore's work, shows the proportions that have been observed in designing some of the best constructed reservoirs. (See Table A, page 5.)

From this it appears that the proportion between the amount stored and the total rainfall varies between one-half and one-fourth.

The rule suggested by Professor Rankine "for estimating the available capacity required in a store reservoir, that founded upon taking into account the supply as well as the demand," is probably the best that can be adopted in designing waterworks for the supply of a town; "for example, 180 days of the excess of the daily demand above the least daily supply, as ascertained by gauging and computation in the manner above described." In order that a reservoir of the capacity "prescribed by the preceding rule may be efficient, it is essential that the least available annual rainfall of the gathering grounds should be sufficient to supply a year's demand for water." In calculating the capacity of a storage reservoir, the consideration of the surface evaporation must not be disregarded, especially when the works are designed for tropical or very dry climates. The amount of loss will in some cases be very considerable, for whatever depth of water be assumed to pass away into the air, it must be regarded as extending over the whole surface of the reservoir; or, in fact, the cubic quantity will be equal to the product of the depth evaporated away and the mean surface area of the reservoir as the water rises or falls throughout the year. Some have gone the length of asserting that the amount of evaporation from the surface of large and

TABLE A.

LOCALITY.	Height above Sea.	Drainage Area.	Total Discharge for the Year.	Discharge per Square Mile.	Representing Rainfall per Annum.	Registered Rainfall per Annum.	Reservoir Room per Square Mile.	Proportion of Storage to available Rainfall.
	ft. ft.	sq. m.	c. ft. per m.	c. ft. per m.	in.	in.	c. ft. in. mill.	
Bann Reservoirs, 1837-38	400 to 2800	5.15	1092.6	210 2	48 0	72.0	56 0	½
Greenock, 1827-28, flat moor	512 to 1000	7 88	1416.6	197.7	41 0	60.0	38.0	2-5
Bute, 1826	200 to 350	7 80	819.0	105.0	23.9	45.4	.....	.....
Glencorse, Pentland Hills	734 to 1600	6.00	600 0	100.0	22.3	37 0	7 66	3-10
Belmont, 1813, moorland.	850 to 1600	2.81	630.4	224.3	50 7	63 4	26.8	¼
" 1844, "	....	.....	412.8	146 4	33 3	50 0	.....	.....
" 1845, "	....	.....	511.2	181 9	41 2	55 0	.....	.....
" 1846, "	....	.....	411 3	146 3	33.2	49 8	.....	.....
Rivington Pike, 1847	800 to 1515	16.25	2880 0	176 7	40.0	55.5	29 6	⅛
Longendale "	500 to 1800	.....	.....	.....	49.5	55 5	.....	.....
Swineshaw "	500 to 1800	.....	.....	.....	37 0	49 3	.....	.....
Turton and Entwistle, 1836	500 to 1300	3.18	576.7	181.3	41.0	46 2	31.43	⅛
" " 1837	....	.....	548.2	172.3	39 0	48.2	.....	.....
Bolton Waterworks	800 to 1600	.80	100 2	125.2	32.7	.....	25.6	1-3
Ashton " 1844	800	.59	40.7	65.5	15.5	40.0	21.0	4-7

deep bodies of water is probably nothing at all, or, at any rate, not worthy of consideration; whilst others assume a much larger amount of loss than appears to be supported by observation. The following extract from the article "Physical Geography," published by the Society for Promoting Useful Knowledge, expresses intelligibly the conditions that tend to promote evaporation:

"Other things being equal, evaporation is the more abundant the greater the warmth of the air above that of the evaporating body, and least of all when their temperature is the same. Neither does much take place whenever the atmosphere is more than 15 deg. colder than the surface upon which it acts. Winds powerfully promote evaporation, because they bring the air into continual as well as into closer and more violent contact with the surface acted upon, and also, in the case of liquids, increase by the agitation which they occasion, the number of points of contact between the atmosphere and the liquid.

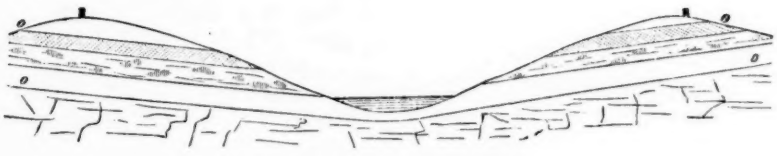
"In the temperate zone, with a mean temperature of 52½ deg., the annual evaporation has been found to be between 36 in. and 37 in. At Cumana, on the coast of South America (N. lat. 10), with a mean temperature of 81.86 deg., it was ascertained to be more than 100 in. in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to 97 in. The degree of evaporation very much depends upon the difference between the quantity of vapor which the surrounding air is able to contain when saturated and the quantity which it actually contains. M. Humboldt found that in the torrid zone the quantity of vapor contained in the air is much nearer to the point of saturation than in the temperate zone. The evaporation within the tropics, and in hot weather in temperate zones, is on this account less than might have been supposed from the increase of temperature."

Thus it appears that evaporation, under highly favorable conditions, may take place to the extent of 9 ft. in depth—an allowance that will demand careful consideration in designing storage works. In India, where from the extreme dryness of the atmosphere the evaporation is found to be considerable, the usual allowance made by engineers for the evaporation from the surface of storage reservoirs is at the rate of ½ in. of depth per diem for eight months in the year. Regarding the results that have been arrived at in Bombay, this allowance would appear to be about double what is necessary, for the observations extending

over five years give a mean daily evaporation of less than ¼ in. In Bombay, however, the atmosphere is much more humid than that experienced on the great table-land of the Deccan; and in Madras, where reservoirs are the specialty, it is probable that the actual loss is not far from being a mean between the two fractions. In Great Britain the mean daily evaporation is found to average less than the the tenth of an inch.

In estimating the quantity of storage water that will result from the drainage of any particular district, it will be essential to consider carefully the geological disposition of the strata characterizing the locality in which it is contemplated to establish the works. This, although a matter that may influence the effectiveness of an undertaking to the extent of success or failure, will appear to the purely practical man to imply a degree of refinement that is uncalled for. There will be no difficulty, however, in showing that the geological conformation of a district may be such as, on the one hand, to materially contribute to the efficiency of a storage reservoir, or on the other to prove so defective that no engineering skill or pecuniary outlay could remedy it. A condition of geological structure perhaps the most favorable that could be imagined is that shown in Fig. 1. This diagram represents a geological section taken at

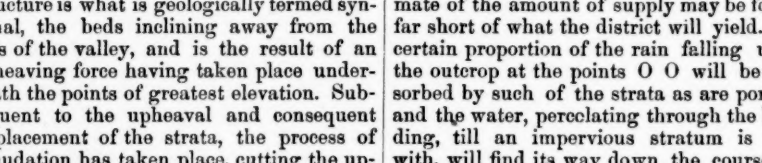
FIG. 1.



SECTION ACROSS SYNCLINAL AXIS.

right angles, or nearly so, to the axis of the valley that it is proposed to convert to the purpose of storage. This somewhat peculiar structure is what is geologically termed synclinal, the beds inclining away from the axis of the valley, and is the result of an upheaving force having taken place underneath the points of greatest elevation. Subsequent to the upheaval and consequent displacement of the strata, the process of denudation has taken place, cutting the upper beds, and leaving the outcrop exposed, not only inside the basin, but in the adjoining valleys at O and O. Now, it is evident that if the highest ridges bounding the valley be taken to mark the line of watershed, and therefore limiting the area of the catchment basin, it is possible that the estimate of the amount of supply may be found far short of what the district will yield. A certain proportion of the rain falling upon the outcrop at the points O O will be absorbed by such of the strata as are porous, and the water, percolating through the bedding, till an impervious stratum is met with, will find its way down the course of the stratification, till it ultimately reaches the reservoir in the form of springs, and contributes more or less to the maintenance of the supply. The converse of this condi-

FIG. 2.

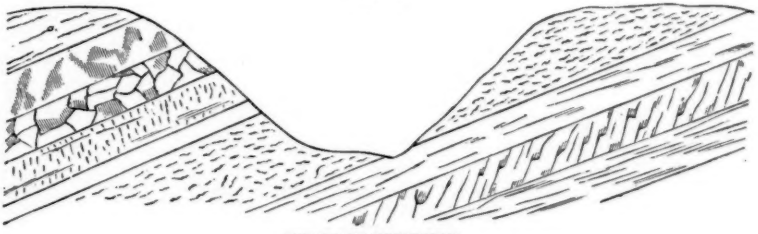


SECTION ACROSS ANTICLINAL AXIS.

tion of things will be readily understood by reference to Fig. 2. It also represents a section taken directly across the valley of the proposed reservoir. Here the strata of the earth's crust incline against each other consequent upon some disturbing force

having taken place to elevate them, and are said to be anticlinal to the axis of the valley. In order to account for the formation of a valley on the summit of the ridge, that at first was thrown up, it is to be understood that the upper beds suffered fracture in the process of upheaval, and subsequently were exposed to denudation. These valleys of elevation are evidently not to be desired as situations for the establishment of storage reservoirs. The area of the gathering grounds will be much more limited than the extent of the watershed would appear to indicate; and cannot safely be relied upon to give an estimate of the quantity of water that the valley will afford. A certain amount of water will undoubtedly pass over the surface in times of heavy and continued rain, before it can be absorbed; but there is no doubt that of all the water absorbed by the ground, by far the greater portion will follow the inclination of the strata, and come out as springs in the adjoining valleys.

FIG. 3.



VALLEY OF DENUDATION.

Fig. 3 shows a geological section that combines in it favorable and unfavorable conditions for the storage of water. On one side the outcrops of the strata are found to extend beyond the highest point of watershed line, whilst on the other side the strata incline away, producing such a condition as would favor the escape from the valley of the water absorbed.

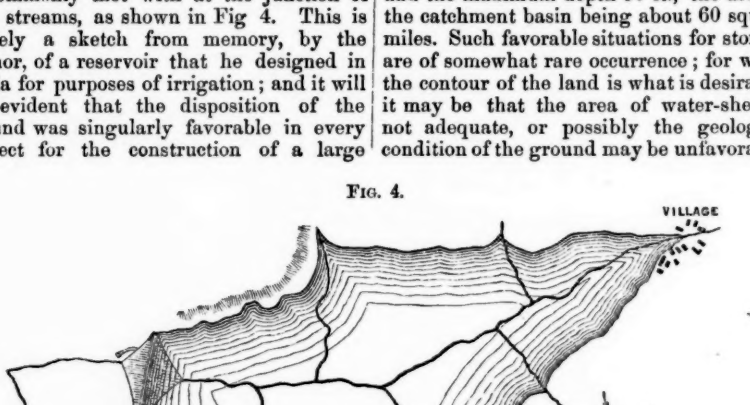
Certain rules are in general use for estimating the quantity of the total rainfall that will be lost by absorption and evaporation, with a view to determining the proper proportion to be observed between the reservoir and the area of the catchment basin. Two-thirds of the whole fall is sometimes taken to represent the loss that may be expected from the drainage of any district, in general terms, one-third being assumed as the amount that may actually be intercepted for utilization. Some authors leave a much smaller margin, and state that fully two-thirds of the total rainfall may fairly be taken as available for storage. This is a large discrepancy when the application of the rules is taken to be general; but when the statements are applied to separate districts and different countries, there is nothing irreconcilable in them. General rules are undoubtedly of much value if they be received with qualification, and are not adopted as of absolutely universal application. They cannot, however, with safety be substituted for specific investigations, when so much depends on starting with accurate data.

RESERVOIR SITES.

The special requirements of each particular case will, as a general rule, go far towards determining the selection of a site for the establishment of storage works. Assuming, however, that there is a considerable extent of country situated advantageously in relative position to the locality at which it is proposed to utilize the water, and that there is a choice of ground, the point to be considered chiefly will be the natural lie of the country. To throw an embankment across a valley at any point without due regard to the configuration of the ground would most probably result in an expensive and ill-designed scheme; for under such circumstances the cost of the dam would bear a very large proportion to the quantity of water stored. It will rarely happen that, in the examination of the resources of any particular piece of country, some special features will not present themselves, favorable to the situation of storage works. The most advantageous disposition of the ground will be when two spurs of high land approach each other, forming a narrow outlet for the stream, and leaving a

wide space above above them in the valley for storage. Such a configuration is not uncommonly met with at the junction of two streams, as shown in Fig 4. This is merely a sketch from memory, by the author, of a reservoir that he designed in India for purposes of irrigation; and it will be evident that the disposition of the ground was singularly favorable in every respect for the construction of a large storage work. The area of the reservoir, as designed, was about three square miles, and the maximum depth 90 ft., the area of the catchment basin being about 60 square miles. Such favorable situations for storage are of somewhat rare occurrence; for when the contour of the land is what is desirable, it may be that the area of water-shed is not adequate, or possibly the geological condition of the ground may be unfavorable,

FIG. 4.



IRRIGATION RESERVOIR.

or the materials for the construction of a sound bank are not available. In examining large tracts of country in India, with a view to the establishment of irrigation reservoirs, the author found that more reliance was to be placed on a careful examination of the map in the first instance, than on the common plan of making personal explorations of the country. A good map will show at a glance, especially if the hill-shading has been carefully engraved, the points at which the supply will be found sufficient to justify the undertaking; and will probably furnish a pretty true indication of sites at which embankments may be advantageously constructed.

In tropical climates, where the rainfall is in places very scanty, and where the land is not of great value, it not unfrequently happens that such situations prove available for the establishment of large storage works as would not under any circumstances be made available in England. These sites are to be found, not at the head of a valley, but at some considerable distance down the course of a stream, where, the general inclination of the country being slight, a low embankment serves to store a very large area of water. The apparent disadvantages of such a site for storage are the large area of land swamped and lost to the cultivator and to Government, and the great surface exposed to evaporation under a tropical sun and the influence of a dry wind. In India, the first objection is one of comparatively little moment, considering that in those districts where irrigation is most required the value of land is very trifling. From 1s. to 2s. is about an average rent per acre, where land is under dry crops; but when water is available, the cultivators can, with profit, afford to pay 30s. per acre. It is therefore evident that, so far as Government is concerned, there is no sacrifice in the matter, but, on the contrary, an unspeakable benefit is conferred

on those landowners who hold farms below the reservoir; and an ample supply of water is stored in the dryest seasons to mature those crops whose failure almost inevitably reduces the people to the verge of starvation. The evaporation from these lakes is, beyond question, a source of very considerable loss, and one that admits of no possible abatement. Estimated as above, at about half an inch vertical for eight months of the year, the loss frequently amounts to one-third of the whole body of water stored. As a set-off against this and other objections, the facilities for constructing these reservoirs of great extent, are considerable. In the first place, the embankments, being very low, are rapidly and cheaply constructed by native workmen; and when finished, the head of water even at the deepest point is not sufficient to try the work to any great extent. Further, the greater the extent of the reservoir, the less inconvenience is experienced from silting. The streams, owing to the suddenness of the rainfall, come down heavily charged with earth in suspension, the mass of which is deposited like a miniature delta at the influx of the reservoir, instead of passing on and resting near the embankment, as invariably occurs in reservoirs of small extent. The immense consumption of water necessary to confer any appreciable benefit by irrigation is of itself the strongest argument in favor of these broad and shallow reservoirs; for it is not possible to find in the upper part of a valley such sites as would store the requisite quantity of water without an embankment of excessive dimensions; and moreover, the catchment area in such situations is not usually sufficient to serve, with a scanty rainfall, for the supply of a very large reservoir. It is not, of course, maintained that this mode of storing water is by any means applicable in England, for the circumstances and requirements in each case are wholly dissimilar.

SUPPLY.

The reservoir site being supposed everything that could be desired, as regards the disposition of the ground, the supply will next engage attention as a matter of course. Assuming that the gathering grounds are sufficiently extensive, it is presumed that the reservoir will be constructed to contain sufficient water to meet the maximum demand, whatever that may be calculated at; and in order to determine with accuracy what capacity the reservoir will have with different heights of embankment, it will be necessary to carry out certain levelling operations over the ground. The least elaborate manner of proceeding will be to run a series of cross-levels through the valley, referring all to the same datum, and by comparing these levels to ascertain what the average depth will be for a given height of bank. Having decided the height of the water-level, the next operation will be to contour round the basin, and to survey the boundary-line. In this way may be acquired sufficient knowledge as to the storage capacity, to justify the procedure with the work. When the execution of the project has been determined upon, it will be advisable to make a more accurate survey of the bed of the valley, and this can best be done by covering the whole plan with a series of contour lines at a vertical distance from each other of about 5 ft. This kind of survey will be of lasting value to the engineer, for it will enable him to calculate what quantity of water the reservoir will contain at each foot of depth; and, consequently, he will know, from a mere inspection of the gauge in the reservoir, how much water he has at his disposal for service.

It has been assumed that the gathering grounds are sufficient to maintain the requisite supply in the reservoir; but it may be well to pause and inquire what extent of water-shed will be sufficient to furnish a given supply, and what method may be adopted for supplementing an insufficient drainage area. It has before been remarked that the only reliable information, when there is any question as to the sufficiency of the rainfall or the area of the catchment basin, can be derived from careful gaugings of the stream or streams that may be depended upon to contribute to the supply. If the catchment area is very large as compared to the capacity of the reservoir, a mere inspection of the map and an exploration of the ground will generally be conclusive as to the sufficiency of the supply for storage. Should there not be such conclusive evidence on this point, it must be determined by measuring the quantity of water that absolutely flows off the ground, at the same time gauging the rainfall. This latter precaution would appear unnecessary, but in truth it is of great value, for it will furnish, by comparison with the rainfall registers that have been kept through the same year,

and a series of previous years, evidence as to the amount of available rainfall that may be expected during terms of comparative drought. If the supply of a town with water be the desideratum, the rule to be rigidly observed is that of making a minimum supply meet the maximum demand, and therefore it is of the highest importance to determine beyond any doubt, what the minimum yield of a catchment basin will be.

As a mode of supplementing an insufficiently large drainage area, catchment drains or feeders have frequently rendered good service. These are cuts that are carried outside the water-shed line to arrest the surface drainage and catch the contributions of small streams, and conduct the water into the reservoir. The greater the area enclosed between catchment drains and the water-shed line, the more valuable will they be as aids to the supply of the reservoir. They of course virtually extend the area of the catchment, adding so many square miles or acres to the rainfall.

DESIGNING OF WORKS.

Knowing the exact requirement of a given population, or rather having fixed, after every consideration, the daily consumption of every individual that it is proposed to supply, there will be no difficulty whatever in proportioning the reservoir to the demand upon it. It is sometimes necessary, however, to provide reservoirs for the purpose of preventing damage to the country by floods, and in this way the inconvenience and injury naturally consequent upon very sudden and excessive falls of rain may be to a great extent obviated. The duty of the reservoir will be to arrest all water in excess of what the stream can carry within its banks, and to dispose of this excess water, so to speak, in detail, after the excessive rainfall has become moderated. A comparison of a stream's discharge, taken at highest floods, with the quantity that it can carry without overflowing its banks will show the excess that has to be retained by the reservoir; and these data can only be arrived at through a carefully kept record of the extent of the floods and of their duration. The maximum flood in this consideration will not be that which rises to the greatest height for a short time, but will be the product of the excess above what the river can discharge by the length of time the flood lasts; which will, in fact, be the necessary capacity of the reservoir.

The Table given on a preceding page will afford an interesting study when compared with the following Table, extracted in part from the same work. The first gives a comparative view of the volume of water gauged and stored in small hill districts, the last column indicating the proportion of the total available rainfall to the amount actually intercepted for storage. The following Table shows the ordinary summer discharge of various rivers, streams, and springs, as unaffected by immediate rain. (See Table B, page 11.)

Where the reservoir is designed to check the injurious effects of floods, the proportion of the storage to the rainfall will, in most cases, be much smaller than what would be necessary to provide for the better part of a whole year's fall of rain. for it is not probable that the maximum known flood can ever exceed the amount that it would be necessary to store for economic purposes.

PROPORTIONS OF BANK.

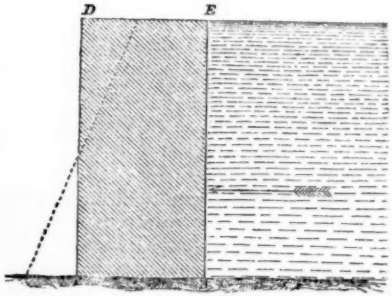
The proper proportion to be given to an embankment for the support of water is a question that appears to admit of a good deal of difference of opinion, some designers taking one view, some another, of the proper theory that is to determine the dimensions of a bank. Some few, with whom the author cannot agree on this point, maintain that a bank ought to be designed with strict reference to its theoretical power of resisting hydrostatic pressure, or the effort of the water to displace it. Regarding the question in its abstract form, it will be evident that any structure intended to sustain the pressure of water may be supposed to fail in one of two ways—either, in the first place, by yielding to the horizontal pressure of the water and overturning, or by progressive motion, *i. e.* sliding on its base. In considering the first theory, that of resistance to overturning, the easiest method of examining the question will be to take a simple example of a vertical rectangular wall, and ascertain what power it exercises to resist the pressure of water. The pressure of water upon any plane surface immersed is known to be equal to the area of that surface, multiplied by the depth of its centre of gravity below the level of the water and by the weight of a unit of water. Generally speaking, the

TABLE B.

RIVERS.	Height above Sea.	Drainage Area.	Total Discharge.	Discharge per Sq. Mile.	Representing Rainfall per Annum.	Total average Rainfall per Annum.
	Valley ft. Hill, ft.	sq. miles.	c. ft. per min.	c. ft. per min.	in.	in.
Thames at Staines, chalk, greensand, Oxford clay, oolites, etc.	40 to 700	3086	40,000	12.98	2.93	24.5
Severn at Stonebench, silurian	400 to 2600	3900	33.111	8.49	1.98	.....
Loddon (February, 1850), greensand	110 to 700	221.8	3,000	13.53	3.01	25.4
Nene, at Peterborough, oolites, Oxford clay, and lias	10 to 600	620.0	5,000	8.45	1.88	23 1
Mimram, at Panshanger, chalk	200 to 500	50.0	1,200	2.4	5.5	26.6
Lee, at Lee Bridge, chalk (Rennie, April, 1796)	30 to 600	570 0	8,880	15.58	3 53	.....
Wandle, below Carshalton, chalk	70 to 350	41.0	1,800	43.9	9 93	24.9
Medway, dryest seasons (Rennie, 1787), clay	.....	481.5	2,209	4 59	1 04	.....
Ditto, ordinary summer run (Rennie, 1787)	.....	481 5	2,520	5 23	2.19	.....
Verulam, at Bushey Hall, chalk	150 to 500	120.8	1,800	14.9	3 37	.....
Gade, at Hunton Bridge, chalk	150 to 500	69 5	2,500	36.2	8 19	.....
Plym, at Sheepstor, granite	800 to 1500	7.6	500	71.4	15.10	45 0
Woodhead Tunnel, millstone, grit	1000	.....	139	....	....	46 0
Glencorse Burn	750 to 1600	6.0	130	21 6	4.9	37.4

unit adopted in calculations is a foot; and the unit of water being taken at a cubic foot, weighing 62.5 lbs., the resulting product from the multiplication of the three quantities will give the pressure in pounds on the surface immersed. Let it be supposed, for simplicity, that water to the depth of 10 ft. has to be sustained by a vertical rectangular wall, as in Fig. 5. It

FIG. 5.



is usual to take but 1 ft. length of the wall for the calculation, though it will not affect the result whether 1 ft. or 100 ft. be the length assumed. We then have the surface under pressure = 10 sq. ft., the depth of the centre of gravity = 5 ft., and the weight of a cubic foot = 62.5 lbs., the product of which quantities gives us 3,125 lbs. pressure on 1 ft. length of the wall. But this pressure is not the whole of the force that the wall has to resist; the leverage that it exerts must also be taken into account. In the example under consideration—viz. that of a vertical plane with one of its sides coinciding with the surface of the water, as in Fig. 5—the whole of the pressure is so distributed as to be equal to a single force acting at a point one-third of the depth from the bottom. Thus, the total force to be resisted by the wall is $3125 \times 3.33 = 10,406$, which is the moment tending to overturn the wall.

It is evident that a certain weight of the wall must be opposed to this overturning force; and as the height of the wall and the length are determined quantities, the thickness alone remains for adjustment. But as a rectangular wall in upsetting is considered to turn upon a single point, F, in the Figure—viz. the outer line of the wall—there will be a certain amount of leverage to assist the wall in resisting the pressure of the water. This leverage

is the horizontal distance of the centre of gravity of the wall from the turning point, F, and when the structure is rectangular and vertical, it is equal to half the thickness. The amount of the wall's resistance will then be equal to the number of cubic feet in one foot of its length multiplied by the weight of a single cube foot of masonry and by half the thickness of the wall. Taking w = weight of a cubic foot of water = 62.5 lbs., w^1 = weight of a cubic foot of brickwork, say 112 lbs., x = thickness of the wall, and h = the height, the conditions of simple stability will be fulfilled when

$$w^1 \times h \times x \times \frac{x}{2} = w \times h \times \frac{h}{2} \times \frac{h}{3} \quad \ldots\ldots\ldots (1)$$

$$\frac{w^1 h x^2}{2} = \frac{w h^3}{6};$$

and solving for x, we get

$$x = \sqrt{\frac{w h^2}{3 w^1}} \quad \ldots\ldots\ldots\ldots (2)$$

the thickness of the wall = 4 ft. 4 in.

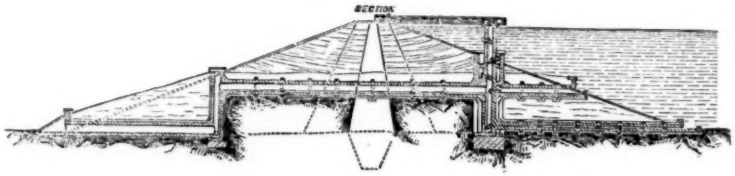
A simple example has been selected for illustration; but of course a rectangular section of wall would not be found generally applicable in practice, nor would it be convenient to limit the dimensions of a retaining wall of whatever kind to the minimum that would sustain the pressure. If this principle of calculation be applied to ascertain the stability of a bank of earth with long slopes of $2\frac{1}{2}$ or 3 to 1, it can easily be shown that in every case the resistance of the bank to overturning is greatly in excess of the horizontal leverage exercised by the water sustained.

The only theory, then, in any degree tenable, is that assuming a bank in yielding to the pressure of water to slide on its base. In order to conceive how this can apply, it is necessary to assume the embankment to be a rigid body resting, for a given length of its section, on a horizontal plane; and without any adhesion, or a very small fraction, existing between the surfaces pressed. The amount of the friction, however, is just the point upon which the whole matter hinges, and until it has been ascertained that the surfaces of earth that are carefully incorporated with one another have any such thing as a co-efficient of friction, it is idle to to pursue the investigation by a mathematical mode of reasoning. The conditions of stability will be satisfied when the horizontal component of the water's pressure against the bank will equal the weight of the bank, plus the vertical pressure exercised by the water to hold it down and multiplied by the co-efficient of friction; but nothing is known of this co-efficient, and consequently the equation remains incapable of solution. As a matter of fact, embankments do not slide bodily forward on their base when they fail, but give way from other causes than mathematical reasoning can supply. Landslips, it is true, to some extent support the principle that maintains the sliding of embankments; but, here, the circumstances are widely different. Landslips either take place when a mass of earth rests upon an inclined surface of rock, with an ample supply of water to lubricate the surfaces in contact, or else they are the result of cutting or embanking earth to a higher slope than the material will stand at; the infiltration of water also in this case is the chief agent in producing the effect, acting as a lubricant, and causing the earth to assume its natural slope. In each case the surface of separation is an inclined plane, an element that does not enter into the question of the stability of embankments, by either of the modes of reasoning above referred to. The principles that direct the design of embankments to retain water are not those that apply to the calculation of the forces to be resisted or the means to overcome them, any more than breakwaters and harbor walls can be designed on mathematical principles. The whole question naturally turns on what slope the material composing the bank will stand at. If earth could be got to remain at a slope of 1 to 1, even though the embankment had no thickness whatever at top, it would be amply sufficient in weight to uphold the water in a reservoir. This, however, cannot be accomplished without the assistance of retaining walls, which would be found in most cases much more expensive than the additional earth required to increase the slope to the angle of stability; and therefore the section is so disposed that the earth shall stand both inside and outside the reservoir at such a slope as will be under all circumstances permanent. These slopes have been determined by long practice and by success and failure in pre-existing instances—that is to say, the limits have been laid down, for it is not to be assumed that all descriptions of earth will fall to exactly the same slope when exposed to the constant action of water

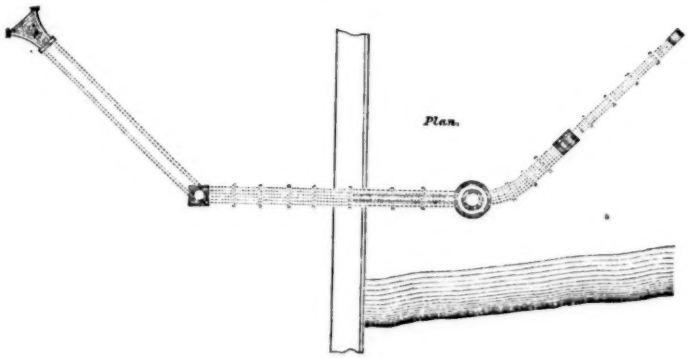
or weather. Earth when subjected to the contact of water almost invariably loses a certain amount of its stability, and therefore it is usual to give the inner side of an embankment a longer slope than the outside. In most of the best existing examples the inside slope of the bank is either 3 to 1 or $2\frac{1}{2}$ to 1, and it is rare to meet any departure from this rule. The outside slope may be designed at from 2 to 1 to 3 to 1, depending upon the character of the material, its power of withstanding the erosive action of the air, and the means used to protect the surface from being washed off or from crumbling away. In designing embankments, the impermeability of the earth is a matter that cannot be relied upon. There are, it is true, innumerable embankments now standing that have never allowed the escape of a drop of water from the reservoir, although no special precaution was taken to make them water-tight. Of these India abounds with examples, the introduction of a puddle wall being in the older embankments of very exceptional occurrence. The earth was merely dug out close at hand, and carried by the workpeople in baskets on their heads to where it was deposited, without any regard to the mode of disposing the material. The author has had occasion to construct a considerable length of levee, or embankment, on this simple plan for the protection of the country from the flooding of a river; and although, so far as he is aware, no flood has yet taken place to test the work, he has, from the study of existing examples, entire confidence in the result. The earth, so far as practicable, was disposed in layers, and before each was completed it was thoroughly consolidated by the tread of the workmen. It is not suggested that the puddle wall should be dispensed with in designing embankments, for the additional degree of safety, in most instances, will more than compensate for the extra expense it entails; but, in low embankments made of good retentive clay, the precaution of puddling is by no means a necessity.

In most of the best examples of embank-

FIG. 6.—No. 1.



No. 2.

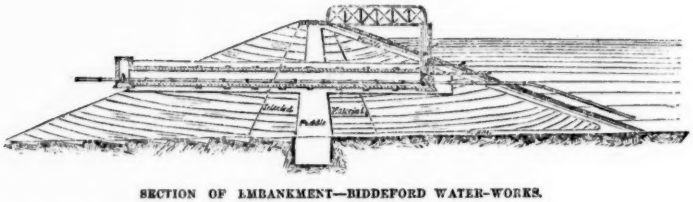


RESERVOIR EMBANKMENT.

ments in England, the practice adopted has been to carry up the earthwork in layers of 2 or 3 ft. in thickness, disposed in the manner shown in Figs. 6 and 7, and at the same time to construct in the centre of the bank a wall of well-puddled clay, the foun-

dation of which is carried down for whatever depth may be necessary in order to reach an impermeable bed of earth or rock. It is not in all situations possible to procure earth exactly suitable and in sufficient quantity for the construction of an embankment, and consequently it is usual and advisable to dispose the best part of the material—that is, the most retentive of water—in juxtaposition to the puddle wall, as indicated in Fig. 6. In this example, the selected material is disposed equally at either side of the puddle; but, as its function is to withstand the admission of water,

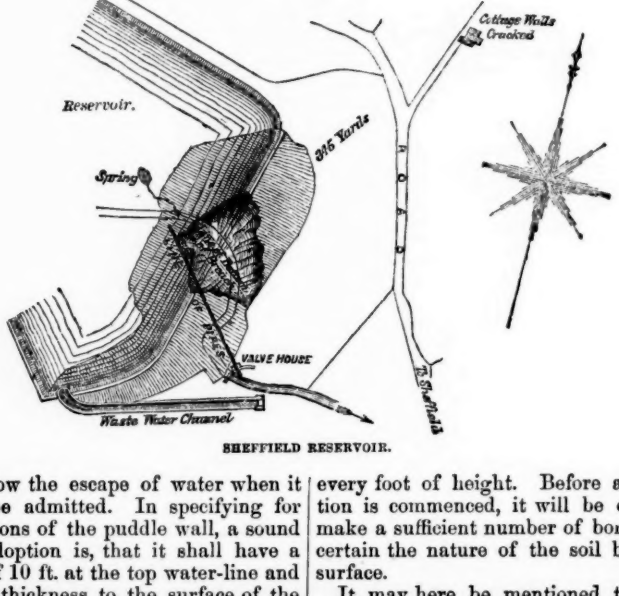
FIG. 7.



SECTION OF EMBANKMENT—BIDDEFORD WATER-WORKS.

it would probably be more consistent, though less in accordance with practice, to place all the selected material on the inner side. The practice of excavating the earth for an embankment from the inside of the reservoir is one that should not be followed without caution. Removing so large a mass of material would, no doubt, give a considerable increase of storage room; but sometimes the bed of a reservoir is covered by a layer of impervious clay that is of immense value, and if this be cut through or removed, it is quite possible that a bed of porous material may be met with suffi-

FIG. 8.



SHEFFIELD RESERVOIR.

cient to allow the escape of water when it comes to be admitted. In specifying for the dimensions of the puddle wall, a sound rule for adoption is, that it shall have a thickness of 10 ft. at the top water-line and increase in thickness to the surface of the ground at the rate of 1 in. on each side for every foot of height. Before any excavation is commenced, it will be essential to make a sufficient number of borings to ascertain the nature of the soil beneath the surface.

It may here be mentioned that professional men are not apparently agreed as to

the principles to be kept in view in constructing reservoir embankments; and this want of concurrence never was more apparent than in the discussion that followed the destruction of the Dale Dyke reservoir, near Sheffield. Fig. 8 shows a plan of the embankment site after the catastrophe. The bank was 95 ft. high, with slopes of 2½ to 1, and a top width of 12 ft. The puddle wall was 16 ft. in width at the ground-line, and tapered to 4 ft. at the top of the bank. This embankment, with the exception of the puddle wall, was composed of rubble stone and shale; an additional price having been given by the engineers to insure the use of the former material; which proves, at any rate, that this mode of construction was adopted on principle and not through ignorance or mistake. From the evidence given by the engineers of the company, it appears that it was, in their opinion, desirable that the inner part of the embankment should be permeable to water, because earth was much more likely to subside and slip than an open and less yielding material like stone. This mode of construction implies that the puddle shall be fully sufficient of itself to resist the passage of water, and that there is no necessity to relieve it of any part of the pressure against it. Of course, if a bank be composed of open work, every point in the face of the puddle is exposed to the full and direct hydrostatic pressure; and if at any point there is the smallest fissure or imperfection, the water has full power against it, and will, to a certainty, take advantage of such point to breach the dam. The assumption, then, of the constructors of this and the Agden reservoir evidently was that a puddle wall of some 25,000 sq. ft. of area was to be constructed without an imperfection of any kind, or a single weak point in the whole surface.

The obvious reason for employing puddle at all, in embankments, is to thoroughly close up any imperfection that may occur in the earthwork; it is in fact merely an accessory, and cannot be relied upon of itself to secure the embankment against destruction. If an embankment be constructed of good sound earthwork, properly executed, it is highly probable that the water may never penetrate half way through to the puddle wall, and probably, in the majority of examples, has not done so. Earthwork, however, is not always executed without imperfection; some decomposable material may be introduced, which, in course of time, dissolves, leaving a fissure; one part may be at first less consolidated than another, and, subsiding, lead to imperfection; or an embankment, be it ever so well constructed, may be burrowed through by moles, rats, and other vermin. It is to meet the first two of these sources of imperfection that puddle is used; and if, by such fissures as may occur in ordinary earthwork, water is admitted as far as the puddle wall, it can only exercise pressure against it at a few points, the puddle and earth being, in good work, so bonded and incorporated with each other that there is no space left for the water to occupy and press against the surface. Most who have read the account of the disaster that occurred in March, 1864, at Sheffield, will recollect how singularly conflicting the professional evidence on that occasion was. Some of our first engineers were ranged against each other in order to satisfy the public as to whether the failure of the embankment was attributable to bad engineering or to a landslip; and although the impression finally remained on the public mind that "there was not that engineering skill and attention to the construction of the works that their magnitude and importance demanded," the engineers were fairly divided in opinion as to the cause of the disaster. One section pronounced, without qualification, that the embankment gave way in consequence of a landslip, and entirely ignored the fact of the embankment being defectively constructed; whist the other gentlemen gave their verdict dead against the company, and their mode of constructing water-tight banks. The two diagrams, Nos. 6 and 7, may be taken as indicating the system of constructing embankments most generally approved of. The puddle, as will be observed, is carried up to the natural surface of the ground without any batter, and from that point slopes on each side to the top of the bank; on either side of the puddle is disposed, in concave layers, the most sound and retentive part of the material; and outside of all comes the ordinary earthwork.

As a security against the eroding action of the water, and also against the inroads of vermin, the most desirable, as well as the most usual practice, is to pitch the whole of the inner face of an embankment with stone, carefully laid by hand. Neglect of this precaution has led to the destruction of

many embankments in other respects securely constructed, and even when ample height of bank above the surface of highest water was provided. In all ordinarily inclement weather the disturbance of the surface of a reservoir amounts to no more than a mere ripple; but when the surface is of large extent, and a severe storm blowing, the waves produced are such as to cause reasonable apprehension, and, in fact, have, before now, overtopped the bank and cut it down, till the water flowed over and caused the destruction of the work. In most cases, it will be necessary to leave about 5 ft. between the level of the highest water and the top of the embankment, and never less than 3 ft.

A mode of construction not very generally used, but apparently consistent with reason, is that shown in Fig. 7, the embankment for the Bideford Waterworks. It consists in covering the whole of the inner face with a layer of puddle, with sometimes a layer of peat outside it. On some occasions it has been thought desirable to mix with the puddle a quantity of small stones or furnace cinders, by way of obstruction to vermin—a precaution that is by no means unnecessary. As an instance in point, the author is reminded of a masonry dam in India that had to be pointed every year regularly, because the fresh-water crabs in the reservoir found it convenient and promotive of their development of shell to appropriate the mortar to their personal use. The joints were cleaned out as effectually at the end of each monsoon as if the work had been done to order.

The preparation of the foundation for an embankment is a matter requiring some care. The soil, consisting of grass, roots, etc., and other matters of a decomposable nature, should be carefully removed over the whole surface to be covered by the bank, and if any porous material, such as sand or gravel, be present, it must be removed, until a compact and water-tight bed is arrived at. The bank must, in fact, be in contact with some sound and reliable material that will not admit the passage of water.

APPENDAGES OF RESERVOIRS.

Under this heading may be considered:

The whole apparatus for allowing the water to escape, including the pipes, the valve tower, and the culvert.

The waste sluices.

The waste weir or by-wash.

The most economical mode of discharging water from a reservoir is through a single pipe passing either through the embankment or immediately under it; but this plan cannot, under any circumstances, be recommended, though it is some times found in existing examples. It is open to several grave objections, the principal of which, perhaps, is that the failure of a joint under the embankment from unequal pressure, or from whatever cause, will probably produce the destruction of the embankment, or at any rate, entail a serious interruption to the supply, by the reservoir having to be emptied in order to repair the pipe. Buried in or under an embankment, a pipe is completely out of reach and out of view, and may be in a very defective state without its being possible to detect the imperfection.

In order to secure the satisfactory working of a reservoir as a source of constant supply, it is esential that the outlet pipes, valves, and all other appendages for controlling and regulating the escape of the water, should be accessible for inspection and repair. The usual mode of accomplishing this is to carry the pipes out through a culvert of brick or masonry of sufficient dimensions to admit a man. This culvert communicates with the valve tower, as shown in Figs. 6 and 7, so that there is a complete communication between the outside of the reservoir and the inside. When unavoidable, the culvert is carried straight under the embankment in the natural ground; but the safest and most generally approved mode of construction is to bring the culvert round the end of the embankment, where it will be out of reach of injury from unequal settlement; a source of no small apprehension when either culvert or pipes alone are carried under the bank. Where possible, it is an excellent plan to run a heading through the solid ground, lining it with brickwork and puddling it, forming a tunnel entirely independent of the embankment. The principal objection to carrying either the culvert or pipes through or under the bank is their liability to fracture from the unequal settlement of the earthwork. It would appear that their liability to damage cannot with certainty be insured by any reasonable depth of excavation, and is, therefore, generally disapproved of by the best authorities.

In the best constructions the culvert is situated half way or two-thirds up the em-

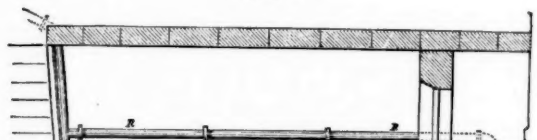
bankment, and in such case the outlet pipes for drawing off the water in the reservoir act as syphons when the water surface has fallen below the culvert. Fig. 6 shows a plan, as well as a cross section, of a reservoir dam designed for general application by Mr. Rawlinson. Here the bottom of the culvert is about 25 ft. above where the inner slope of the embankment intersects the ground at the lowest point. The syphon pipe is also shown passing through the culvert; the horizontal culvert is connected with a shaft inside the embankment, in which are placed the valves for leading off the supply from the reservoir. The valves are made to be closed on the inside by valve spindles and screws, and the inlet pipes are closed on the outside by plugs which can be applied from the top of the valve-tower. Thus the engineer has full command of the whole of the outlet works; all the pipes and valves are easily accessible and under perfect control, so that the supply can at any time be arrested for the repair of any derangement that may occur, even to the removal and replacement of all the pipes. The inlet pipes are shown in this example, as well as in Fig. 7, fixed at different heights in the valve-tower, the object of which is to draw the supply from the reservoir from points near the surface. The outlet pipe, passing through or under the embankment, may be connected on the inside of the reservoir by a flexible joint with another pipe of the same diameter, to the upper end of which is attached a float. This pipe is movable in a vertical plane, being controlled from lateral motion by the guide-posts. Such an arrangement admits of the water being drawn off from the surface, where it is least liable to be contaminated with impurities. Whatever arrangement be selected for drawing the supply off from a reservoir, the system of carrying the pipes, either with or without a culvert, through or under the embankment, cannot be sufficiently deprecated; they are, in such a position, beyond the reach of inspection, and, moreover, are very likely to induce leakage from the reservoir. It is usual to puddle carefully the culvert or pipes when carried under or through the bank, but, even with such a precaution, the water has under a considerable head a tendency to creep along the pipe, and, by soaking into the earthwork, may cause any one of the many evils that imperil and destroy embankments.

When embankments are not of great height, an exceedingly cheap and simple mode might be adopted for drawing off the water. This would be by laying a syphon over the embankment, as was done in the case of the middle-level drainage in Cambridgeshire, which syphon would at the inner side have a flexible connection with another tube having a float attached, as above described. Such an arrangement would apply in principle to heights not exceeding 30 ft., as the pressure of the atmosphere would maintain no greater height. In practice, however, the syphons cannot be worked with success at much above 20 ft., for it is found that after a short time, the flow becomes arrested by the collection of air in the upper part of the syphon, and it becomes necessary to pump the air out constantly, to prevent it from interfering with the flow, as it would do if not removed. It would appear a simple matter, where it is desirable to adopt a syphon, to utilize the power of the water flowing out for the purpose of getting rid of the air; it might easily be applied, through a small wheel and suitable gearing, to work an air-pump fixed at the highest point of the syphon, making the whole arrangement self-acting. The arrangement could be successfully applied to irrigation tanks in India, where the embankments are frequently less than 30 ft. Each leg of the syphon should be provided with a valve to retain the water, and when the supply was intermittent it would be essential to have an opening at the highest point of the syphon, and some appliance, perhaps an air-pump, for filling it with water in case of leakage.

To insure a constant discharge from a reservoir with a constantly varying head, several methods have been adopted; of these, one of the most ingenious is that used at the Gorbals Waterworks, near Glasgow. Fig. 9 represents a transverse section through the regulator-house, showing the arrangement by which the discharge is equalized. To the orifice of the outlet pipe, O, is fitted a square-hinged flap valve of wood, against which presses, by a friction roller, a lever, B, the arms of which are bent. To the upper arm is attached a chain that passes over a pulley, and is connected with a cast-iron cylinder or float, D, that stands in the reservoir, E, of slightly larger diameter. At the side of the entrance-door of the building is placed another cistern, G, of cast iron, closed at top, and communicating

by a pipe, R R, with the vertical pipe, H, which is in connection with the outlet pipe, and passes up the slope of the embankment, to carry away any air that may accumulate in the main. The cistern, G, is connected with the reservoir, E, by a pipe, K, which supplies water to float the cylinder, D. Now, it is evident that the discharge from the reservoir will be regulated by the position of the lever, B, and this again will be controlled by the height of the float, D. To regulate this height the supply from the cistern, G, must be self-adjusting, or be regulated by the amount of water flowing away. The float, N, has attached to it a spindle, on which are fixed two double-beat valves that work in the vertical part of the pipe, K, one of which

FIG. 9.



admits water from the cistern, G, into the cylinder, E, and the other allows the water to escape from the reservoir, E. Now, if the surface of the water upon which the float, N, rests should rise above the proper level, the float forces up the spindle, closing the supply valve from the cistern, and at the same time opening the lower valve. Thus the supply is cut off and the escape opened, enabling the float, D, to fall. The subsidence of the float closes more or less the flap valve, and checks the discharge, in consequence of which the surface of the water falls, and with it the float, N, which consequently opens the supply valve, and again admits water into the cistern, E. Thus an almost perfect equality between the consumption and the supply of water is preserved. It would appear that the same effect could be produced by connecting the lever directly with a float on the surface of the water, but such an arrangement would only apply when the pressure against the flap is trifling.

It is essential that every reservoir should be provided with some means of getting rid of the excess of water that flows into it, and whether this provision be made by a waste weir, sluices, or waste pit, it is one that should not be omitted. The most advantageous position for a waste weir will generally be at some point remote from, and entirely unconnected with, the embankment, and occasionally a natural depression in the ground, as shown in Fig. 4, will afford remarkable facilities for the construction of an escape. The level of the crest of the waste weir with reference to the top of the dam will require to be carefully adjusted, the minimum difference of level being 3 ft., and the maximum about 10 ft., depending on varying circumstances. The height of the waste weir will, of course, regulate the top water level in the reservoir; and this must be fixed with regard to the probability of the embankment being overtopped by waves. The circumstances influencing the height of the waves in a reservoir are the extent of the water surface, the depth, and the amount of exposure to or shelter from wind, all of which will vary with each particualar case. Under ordinary

circumstances, the height of the top of the embankment above the crest of the waste weir should be for

an embankment 25 ft. deep, 4 ft.
" 50 ft. " 5 ft.
" 75 ft. " 6 ft.

and for greater height of embankment the difference of level may be proportionately increased.

When the configuration of the ground does not afford any facilities for the construction of a waste weir after the manner described, sufficient provision for the escape of the overflow is made through a waste pit. This waste pit, or tower, is generally a circular structure built over the outlet culvert inside the reservoir, and serves equally for access to the valves and for the escape of the flood water. With regard to the capacity of the waste weir or waste pit, whichever be adopted, it will be necessary to make ample provision for the discharge of the sudden accessions of flood water that reservoirs are subject to, and which so seriously imperil their safety. To provide for this there is an empirical rule amongst engineers that is supposed to suffice for the most urgent contingencies. It states that there shall not be less than 3 ft. of length of overfall for every hundred acres of gathering ground, but it is obvious that to proportion the length of the waste weir to a given area of country in all cases would be unreasonable.

The discharge over the weir will not depend only upon the quantity of rain falling on a certain area of ground, but also on the extent of the reservoir as compared to the gathering ground, and on the flat or precipitous character of the basin. The only safe mode, then, of proportioning the length of the escape will be to ascertain with exactness what the discharge of the stream or streams flowing out of the reservoir was during the greatest known flood, and then fixing upon an arbitrary depth for the water to flow over the weir, say 2 ft. or 3 ft., to calculate what length of overfall will suffice for the discharge of the excess water. In India, where large waste-weir accomodation is essentially necessary, while it is equally a necessity to save every gallon of water that is possible, it is a common practice to form a temporary dam, of earth and sods, on the top of the waste weir; this serves to pond up some 3 ft. or 4 ft. of water over the whole surface of the reservoir, and does not imperil the security of the works. In times of heavy floods the water rises and overtops the temporary dam, and no sooner does so, than the whole is carried away, and the water in the reservoir quickly subsides.

In works designed for the supply of towns, it is sometimes necessary to make provision to arrest the entrance of flood-water into the reservoir, as the streams may come down charged with large quantities of matter in suspension that would injure the purity of the water for domestic consumption. These streams may be diverted and carried round the margin of the tank past the dam, and can be admitted into the channel of the stream, or be utilized for mill power. On the Manchester Waterworks are constructed across the mountain streams weirs of an ingenious design, for the purpose of separating the flood-waters from the ordinary flow. The dimensions are adjusted from observations of each particular stream, so that the discharge up to a certain amount will take place into the channel for the supply of the town; but when the discharge increases, and the water becomes turbid, it has sufficient velocity to carry it over the opening, as shown in the diagram, and flows down to the compensation reservoir for the supply of mill power.

In determining the dimensions of a weir of this kind it is first to be ascertained what the mean velocity of the water flowing over will be for a given depth of water, h, above the crest. The mean velocity, v, will be

$$v = \frac{2}{3} \times 8.024 \sqrt{h} = 5.35 \sqrt{h}.$$

If the vertical height of the crest of the weir above the point to be overleaped by the cascade be called x, the distance across will be

$$y = \frac{2v\sqrt{x}}{\sqrt{2g}} = \frac{4}{3}\sqrt{xh}.$$

Before concluding, it will be well to give a brief consideration to the causes tending to the failure of embankments. The foregoing remarks will, in suggesting the best mode of construction, have anticipated much that might be said on the subject of failures; but there are a few points, the recapitulation of which the importance of the subject demands.

There are unfortunately on record, accidents, if they can be so called, from the

bursting of embankments, that if estimated by the loss of life attending them, are as appalling as anything within the memory of man. Thousands of human lives have been sacrificed to ignorance and false economy, as well as in some instances to natural defects that it would have been difficult to foresee.

The existence of springs on the site of an embankment is an undoubted cause for apprehension, and considerable care should be taken to carry all water from this source away, that it may not, as it certainly will if not checked, force its way between the surface of the ground and the seat of the embankment. In doing so there is every probability that the earth of the embankment will be washed out by constant trickling till a fissure is formed of sufficient dimensions to render the destruction of the bank a certainty, if the water from the reservoir should ever penetrate so far. As a provision against this source of injury, all springs found on the site of an embankment should be taken up and carried away in proper drains sufficiently and securely puddled. Thus the water is confined to a single channel, and has no tendency to soak into the earthwork and blow it up in endeavoring to escape. In embankments of all kinds the presence of water is a most serious evil, and one by which may be accounted for, some of the most extensive land slips that are on record. It is erroneous to assume that when water is the active element in producing disruption in an embankment or mass of earth of any kind, that it only acts as a lubricant between the surfaces in contact. The truth is, the bulk of earth is sensibly affected by the amount of moisture in it, as is seen in the subsidence of newly-formed railway banks when exposed to rain. If, then, a sufficient quantity of water find its way into the centre of a bank that has been put together in a comparatively dry state, it will rise and soak into the earth until at length what was a solid mass becomes semi-fluid, settles into a smaller space than it before occupied, and, as a consequence, will leave a vacuity above it. The inevitable result is the subsidence of the superincumbent earth; but instead of resting, as at first, on a resisting material, it floats, so to speak, on the semi-fluid mass underneath, and having little or no friction to overcome, slips away to a lower angle than it before stood at. Natural springs, therefore, whenever they occur, must be dealt with carefully and completely. Exactly similar effects to those produced by natural springs may result from the defective practice of carrying outlet pipes through or immediately under embankments. Be the pipes ever so well puddled, there will be a tendency to trickling along the line of their direction, and assuredly if this trickle makes its way to the centre of the bank it will carry mischief with it. It is true that springs are occasionally found issuing from the foot of an embankment, without after several years causing any appearances to justify apprehension. The Doe-park reservoir is an example in point, and though at one time fears for its safety were entertained, the embankment is still standing, and, so far as the author is aware, the spring is still trickling away. An engineer of eminence was called upon to report upon the state of the works, and gave his opinion that, as the spring came away without any earth in suspension, there was no mischief taking place, and that the work was in a safe condition. There is no doubt that embankments in this condition require to be narrowly watched, although the presumption may be that, having lasted for several years, they will continue in safety.

The empirical and unscientific mode of proportioning the length of waste weirs has proved before now a source of danger and destruction to embankments, from the space afforded not being sufficient to discharge the excess water without the surface rising to such a height as to top the embankment. To avoid risk, the stream must be gauged with great care, and the discharge calculated for the greatest known flood; and if with a given head the length of the weir be adjusted to discharge this amount, or a little in excess, there will be no risk to the embankment.

Regarding finally the whole subject, the danger that may result from careless or unscientific construction, the large outlay entailed in the establishment of storage works, and the benefit that may accrue from them whatever their purpose may be, the subject cannot be undertaken on merely rational grounds. Its successful application will rest alone on the study of the question in its scientific details, and an ample practical experience.

DISCUSSION.

Mr. H. P. Stephenson said he entirely agreed with the author as to the impro-

priety of carrying a pipe through the embankment of a reservoir. He would extend his objection to the passing of a culvert through the embankment. If the culvert were laid on the natural ground, they would avoid the risks pointed out by the author, either of the settlement from the joints of the pipe, or of the water creeping along between the material and the pipe. He believed that the true principle of construction for reservoirs was the placing of a good puddle dam in the centre, and on each side of this dam layers of earth well punned in. One reason why he should prefer the puddle wall in the centre was that there was less tendency in the puddle to slip in such a position than when laid on the slope.

Mr. Albert Latham agreed with Mr. Stephenson in his remarks as to the pipes and culverts; but he thought it was an open question whether the puddle wall should be in the centre of the dam. He had a strong opinion that it should be on the face of the dam.

Mr. Cargill said that he believed that the reason the puddle wall was not required in Indian embankments, referred to by the author of the paper, was that the earth seemed to have been thoroughly consolidated by the continual trample of people upon it. That thorough consolidation was the great point in all puddling, and it was on that account that specifications were generally so stringent as to the thickness of the layers of the puddle. As to the position of the puddle wall, he could not see the particular value of having it in the middle of the dam, and he thought that a far better place for it would be the face, because the object of the puddle wall was to prevent the infiltration or the escape of the water. This could be effected by puddling the whole slope right down to the permanent strata. The puddle wall was not required to promote the stability of the dam. The question of putting pipes or culverts under the dam required more consideration. It was alleged that the putting of a naked pipe through the dam of the Bradfield reservoir was one of the causes of its bursting. In some very large waterworks now being constructed in Dublin there were two distinct sets of main pipes, and they were laid in two large culverts at the bottom of the dam. The culverts were large enough for a man to walk upright in them. If the foundation were well looked after, there would be no fear of the arch or dome of the culvert giving way in consequence of any inequality of pressure above it, as, if properly constructed, an arch would stand any amount of pressure short of what would crush the material.

Mr. Baldwin Latham said he could not agree with Mr. Jacob that a dam could not be constructed from theoretical deductions; for unless regard was paid to theoretical considerations there might result either a deficiency of strength or a waste of material and labor. In the dam shown in the drawings, and designed by himself, the pipe did not run through, but on the outside of the dam, on the solid ground. It was a well received opinion among engineers that if you had a pipe or culvert running through an embankment, that pipe or culvert would be unsafe. He believed that well made and properly tested pipes were quite as safe as culverts when in the solid ground. A pipe was simply a small culvert made of iron instead of brickwork. In cases in which there was a tendency for the water to creep along the outside of the pipe, that might be stopped by having projecting flanges on the pipe. The same creeping of water might take place along a culvert as along a pipe. With regard to the slope of a dam, the inside slope should be greater than the outside slope, because the greater would be the stability of the dam, and the water would have less destructive effect on the dam; he had effectually prevented leakage by the use of socket-pipes. The square projection of the sockets was alway presented to the reservoir, and the pipes were laid in the virgin ground. It was very bad practice to lay the pipes in made ground, and especially through a dam. Pipes laid under a dam should be tested under pressure after being laid and before being covered up, so that any defective joint might be discovered. In cases in which he had laid pipes through dams, they had been so tested, which resulted in good and effective work; but he was bound to say that, if the pipes had not been tested *in situ* the result would not have been satisfactory.

Mr. Schönheyder said that Mr. Jacob had said that wherever springs occurred they should be well carried away. He (Mr. Schönheyder) wished to know how a spring was to be prevented from diffusing through the earth.

Mr. Hendry said that he had seen pipes which were laid through embankments,

but had never seen one that was perfectly tight. It was almost impracticable to make it so, owing to the continuity of the puddle being disturbed at the point where the pipe passes through.

The Chairman asked what was the largest diameter of pipe Mr. Hendry had seen used.

Mr. Hendry replied that the largest was 18 in. He had heard of several methods being tried, but he did not think it was possible to prevent leaking, more or less, from the reservoir along the outside of the pipe. He should like to be informed how it was possible to connect the puddle with the pipe; if the pipes be laid in the natural ground below the foundation of the embankment, then there is no fear of leakage, provided the pipes are properly laid.

Mr. Jacob, in replying to the discussion, said, that in the opinions that had been expressed there were but few points of disagreement with those that he himself held. He could not agree with Mr. Latham in his belief that embankments could be calculated on mathematical principles. In order to deal with embankments theoretically, they must be regarded as rigid masses, and be assumed to rest upon a horizontal plane. It could be shown mathematically that a rigid body of the same specific gravity as ordinary earth need not present the same section as is usually given to embankments, in order adequately to resist the pressure of water. A right-angle prism with the hypothenuse resting upon the plane would be quite sufficient to resist the pressure of water, even supposing the surface of the water to coincide with the upper edge of the prism. The reason of giving long slopes to an embankment is discoverable from the fact that banks, when exposed to the action of water, are found to waste and slip away to such an angle as will withstand the action of the water. The chief reason of the failure of embankments is the infiltration or soaking of the water from the inner side, which renders the material semi-fluid and causes it to subside into a smaller space than it originally occupied. The superincumbent mass then sinks and allows the water to overtop the embankment. The earth used for making embankments in the Deccan and in parts of the Madras Presidency in India is of a most suitable quality for the purpose. It is what is called "black soil," being very dark in color, and of a highly argillaceous character. The color is, no doubt, due to the presence of carbon. The clay makes most excellent puddle; but, no doubt, the consolidation produced by the tread of the work-people is the real secret of the earth resisting the pressure of water so successfully as it does. In North America, the levees for protecting the country from flooding by the Mississippi are sometimes constructed simply of sand; and are found, for the most part, sufficient for their purpose. As regards carrying away springs from the seat of an embankment, there is no difficulty in ascertaining where they exist when the ground is laid bare, as they are generally well defined streams. Before the earthwork is commenced it is necessary to construct drains of masonry, or brickwork, or to lay iron piping to carry away the water clear of the work.

The Chairman said that the paper of Mr. Jacob was a very interesting one, and the subject was one which, during the last year or two, or, he might say, within the last week or two, had commanded the attention of the whole body of engineers. Last session a special Act of Parliament was passed that all reservoirs and embankments should be constructed to the approval of the Board of Trade. The subject of irrigation in India, which was alluded to in the paper, was one of vital importance. There was no question that the only means we had of irrigating that country in an efficient manner was by the construction of reservoirs.

LIQUEFACTION IN STEAM CYLINDERS.

From "The Engineer."

A correspondent has appealed to us for information on a subject of considerable importance. It will be seen from his letter, which will be found in another page, that he wishes to know to what extent liquefaction takes place in a jacketed cylinder. It is impossible to reply very briefly, and yet satisfactorily, to such a question; and we therefore propose to consider the matter here at more length than we could con-

veniently do in that column which is devoted to solving the various problems placed before us by our readers from week to week. What we are about to say may be taken in some sense as a sequel or appendix to two articles which recently appeared in our pages on indicator diagrams; indeed, it is impossible to properly answer our corrrespondent "Enquirer" without reference to a diagram.

Liquefaction, or, as it is popularly called, condensation, in steam cylinders, is a complex phenonemon—complex, that is to say, as regards its origin. It results from two causes: (1) the cooling down of the metal of the cylinder during the exhaust; and (2) the condensation due to the performance of work. It is possible to estimate the amount of liquefaction due to the second cause with great accuracy in any given case. To predict with certainty the amount due to the first cause is almost, if not altogether, impossible. We shall deal with the second case of liquefaction first, and we may premise that those who wish to see the problem treated in a strictly mathematical sense will do well to consult Rankine "On the Steam Engine," page 385, *et seq.* It is our purpose, however, to handle the question in a different way, so that the principle involved may be rendered as intelligible as possible to those who possess little mathematical knowledge.

A unit of heat is that quantity of heat required to raise 1 lb. of water 1 deg. Fah. in temperature. We speak here of quantity of heat, not because heat is a separate and distinct entity, as it was held to be under exploded antiquated theories, but because the word "quantity" expresses something different from intensity, which is alone measurable by the thermometer. To put this plainly, it will take twice as much heat to raise 2 lbs. of water 1 deg. as will suffice to raise 1 lb. of water 1 deg.; but the thermometer will show only a rise of 1 deg. in both cases. A pound of steam at atmospheric pressure contains in round numbers 1,147 units of heat; in other words, as much heat as would raise 1,147 lbs. of water 1 deg. Fah. Now, in the physical world nothing is to be had for nothing; and we cannot have work from a steam engine without loss of heat from the steam. A unit of heat represents 772 lbs. lifted 1 ft. high, or 1 lb. lifted 772 ft. high. In other words, a unit of heat is the equivalent of 772 foot-pounds, and as much work is done in raising 1 lb. of water 1 deg. as would suffice to raise the same 1 lb. of water bodily to a height of 772 ft., or say to three times the height of one of the water towers at the Crystal Palace. But 1 lb. of steam at atmospheric pressure contains 1,147 units of heat, and therefore represents $1{,}147 \times 772 = 885{,}484$ foot-pounds. Now a horse power is 33,000 foot-pounds per minute, and

$$\frac{885{,}484}{33{,}000} = 26.8.$$

In round numbers each pound of steam at atmospheric pressure condensed per minute, represents 27 horse power. An engine, therefore, working to 27 horse power, with steam at atmospheric pressure, must of necessity liquefy in its cylinder 1 lb. of steam per minute. From this there is no escape. If a jacket is employed, then the liquefaction may take place wholly in the jacket; or, as is usually the case, it will take place partly in the cylinder and partly in the jacket. But how much will take place in the jacket, and how much in the cylinder, depends on some dozen conditions, the influence of which it is impossible to determine beforehand, such as the thickness of the cylinder walls, the conductivity of the metal, the temperature of the steam in the jacket and in the cylinder, and so on.

Hitherto we have spoken only of liquefaction as regards steam of atmospheric pressure. But the amount of liquefaction is very little affected by the pressure. Thus, if the initial pressure of the steam was 85 lbs. on the sq. in., the total number of units of heat contained in 1 lb. of it would be in round numbers 1,182 instead of 1,147, a difference so small as to be practically unappreciable; and if the weight of steam condensed be independent of the pressure, it is equally independent of the point of cut-off, the ratio of expansion, and every other consideration. For each 27-horse power indicated 1 lb. of steam is returned to its original condition of cold water. This loss must take place, and in one sense it is not to be considered a loss, since it is the equivalent for work done.

It may be asked when and where the condensation takes place, but this point we shall not stop to consider. It is enough that in steam engines, as ordinarily constructed, it takes place in the cylinder. We have heard it argued that the liquefaction is caused by the expansion of the

steam. Thus the temperature of steam at 85 lbs. pressure is 370 deg., while that of steam expanded to 15 lbs. above a vacuum, or atmospheric pressure, is 212 deg, and it is assumed that the fall in temperature causes condensation. But this is totally erroneous. A pound of steam at 85 lbs. contains as we have seen 1,182 units of heat, but 1 lb. of steam at 15 lbs. above a vacuum only requires 1,147 units to maintain it uncondensed; therefore, in expanding without doing work from 100 lbs. absolute—85 lbs. nominal—pressure, to 15 lbs. absolute pressure, 1 lb. of steam, instead of being condensed, will actually be slightly superheated, the difference between 1,147 and 1,182, or 35 units, being left free to operate in superheating the steam. If then steam is superheated in expanding without doing work, and if liquefaction takes place when work is being done, it is evident that the doing of work is the cause of liquefaction; and the amount of liquefaction must, as we have said, be determined solely by the work done, and not by the grade of expansion, which can only operate in the sense that the lower the grade of expansion the less will be the liquefaction due to the cooling of the cylinder, for reasons which we have often explained.

It must be clearly understood that the liquefaction due to work has nothing whatever to do with the condensation which ordinarily takes place in all steam cylinders. What this loss will be it is impossible under any circumstances to determine, except by actual experiment, save in the case of twin engines. Knowing the loss in one, we can say with some approach to truth that the loss in the other will be nearly the same. In all cases, the liquefaction due to cylinder cooling is very much greater than that due to work done. We believe that there is no recorded instance of a trustworthy character in which less than twice as much steam as is thoretically necessary to produce a given power has been used; and only in very good engines indeed do we ever find the weight of steam condensed less than three times as much as would suffice theoretically to develop a horse-power per hour. This is the great defect—the crying evil of the steam engine—and it does not appear that it can ever be overcome until some genius apparently yet unborn supplies us with a non-conducting cylinder.

ON THE INFLUENCE OF TEMPERATURE ON THE ELASTIC FORCE OF CERTAIN FORMS OF SPRINGS.*

By Mr. F. H. WENHAM, C E., Vice President R. M. S.

From "The Engineer."

At the last meeting of the British Association' at Brighton, Professor Philips brought forward some remarkable facts relating to the aneroid barometer, showing that in new instruments a permanent set, or difference of indication, is caused by high temperatures, and that a number of alterations of heat, extending over some period of time, are required before the elastic plate becomes completely seasoned, so to term it, to insure regularity in the indications.

It has been long known to meteorologists that thermometers, though accurately graduated at first, acquire after a few months, an index error of sometimes two or three degrees, arising from a tendency of unannealed glass forming the material of new bulbs partly under tension to return to a state of equilibrium with a consequent alteration in capacity, thus showing the propriety of seasoning the instruments by repeatedly subjecting them to the extremes of temperature they are capable of bearing before finally setting them to scale. In connection with instruments for measuring and regulating time, force, or temperature, some of the properties of elastic plates, rods, or springs, may be first mentioned. Their value in these applications depends upon the law that the spaces or degrees of motion are exactly as the forces; that is, if a force of 100 lbs. be applied, each space due to this division of the scale will indicate 1 lb. This law relates only to bodies of certain form, such as a bar supported at one or both extremities, weighted at the end or middle; in a rod subjected to torsion; to a spiral spring either extended or compressed (the opening or closing of the coils in either

* British Association, Section A.

case is virtually a torsion of the wire). This property of equality of force and motion is also identified with the time in which those motions are performed; and the last law follows upon the preceding one, for if symmetrical forms of springs whose deflection indicates equal degrees of space be set in vibration, such as a rod supported at one or both ends, like the tongue in a musical-box, the wire of a piano, or the metal plate of a gong, it gives the same note, whether the vibrations are great or small, proving that the motions are performed in equal times. Such springs are termed isochronal. The flat or spiral coil springs used for the balance wheels of watches and chronometers are not strictly isochronal, for in winding up the spring, as the tension increases, equivalents of force are not represented by equal spaces, which diminish. On the other hand, when the spring is unwound within certain limits the spaces become slightly greater. An instrument was used by the author for testing these points, consisting of the five inner coils of an ordinary watch mainspring fixed to a central pivot, having a pulley round which a thread was wound with a receptacle at the free end for weights. The outer end of the spring was fixed in the same way as the balance spring of a watch; the spring and its attachments were on one side of a metal plate, the other having a circular dial suitably divided. The forces were indicated by a hand attached to the end of the pivot. Within the limits of one revolution only the forces, both in winding and unwinding, were so nearly equal for all divisions that a difference could scarcely be determined, and the slight variation that takes place in the arc of vibration in a well-made timepiece or chronometer with an equalized maintaining power, would render the difference incalculably small, and the balance springs, whether of the archimedean, spiral, or flat helix form, may be considered as practically isochronal. According to the test of additional force in winding, the vibrations should be quicker with increasing arcs; but this tendency is probably nearly neutralized in the opposite extreme, where in unwinding, the forces diminish with an opposing compensating loss of time.

For the purpose of ascertaining the influence of heat on the elasticity of the spring at equal degrees of tension within one revolution, the back of the dial plate was enclosed in a metal box. A thermometer was set so that the degrees could be read off on the projecting stem. A gas jet was brought under the arrangement, which formed a closed oven with the interior, presumably of uniform temperature at the various trials. The spring was first wound by weights to half a revolution, the thermometer indicating 80 deg.; as the mercury rose to 200 deg. there was a visible forward movement of the hand indicating a gradual loss of elasticity. At 300 deg. the deflection was $1\frac{1}{2}$ divisions beyond the 100 into which the dial was divided. At 400 deg. the loss was $3\frac{1}{2}$, at 500 deg., $5\frac{1}{2}$. On allowing the whole to cool down to 80 deg., the hand returned or fell short of the first indication before the application of heat by three divisions. The spring was now weighted to the entire revolution. At 300 deg. the deflection increased by three divisions, at 400 deg. to seven divisions, and at 500 deg. to eleven divisions. On returning to the normal temperature of 80 deg. the spring had taken a permanent set, or went beyond its first deflection to the extent of five divisions, showing that at this temperature and degree of compression the loss of elasticity was 5 per cent. of the total force.

These experiments only served to demonstrate the principle, and were not continued, because the arrangement was too complex to be exact. The friction of the pinion is a source of error; and it appeared to be difficult to establish a law from results obtained this way. Such a law or principle would be important, considering that the compensation given to the balance of chronometers is almost entirely for the purpose of counteracting the loss of elasticity by use of temperature in the coiled spring itself, and so by a decrease of central force increasing the rate of the vibrations according to a known regular law, to compensate for the weakened force of the spring in an irregular and unknown law. The mode of conducting the experiments was now varied so as to represent the elastic plates of an aneroid barometer. Two pins were inserted 13 in. asunder in a slab of slate. Across these the materials to be experimented upon were laid. They consisted of a bright hard drawn steel wire, one of brass, and a thin strip of window-glass; these weighted in the middle gave divisions equal to the forces. A thermometer was placed with its bulb just above the middle of the bars to be tested, so that the temperatures could be easily read off. A stand supported the slate

tablet, which was approached more or less to an ordinary open fire as required, the radiant heat giving a satisfactory even temperature. The deflections were ascertained by a pointer on a finely divided scale. The results of these trials can only be taken approximately. As there was no arrangement for multiplying the motions, the fine divisions were exceedingly difficult to read. In the steel rod with various weights suspended the ranges of deflection increased from the temperatures, 100 deg., 200 deg., 300 deg., 400 deg., and 500 deg., in the irregular ratio of 3, 4, 6, 10, 18, the total deflection amounting to four tenths of the range of compression before the application of heat. When cool, with the weights suspended, the rod did not return to its first position, but had taken a permanent set equal to one-third of the range. The brass wire tried under similar circumstances was comparatively so devoid of elasticity that the first few degrees of heat caused a visible deflection, which continued nearly equally till the 500 deg. was reached; the wire was then deflected a distance of two-thirds the normal range of compression. The glass rod under the same conditions at 500 deg. increased the distance by near one-seventh of the range of compression, but the elasticity due to a strip of thin window-glass is so small that the ratios of the temperatures before-named could not be clearly ascertained, and the permanent set when cool amounted to only one-fourteenth of the compression, showing an advantage in the elastic properties of glass when tried this way visible, if not clearly measurable.

It appeared that experiments conducted according to this plan could not satisfactorily determine a law, even if the deflections were indicated by a dial movement, for multiplying or giving ranges of greater visibility, as every moving part must be a source of error liable to derangement from heat. The experinents were, therefore, next performed in a much more practicable and manageable way, by which short strips or springs of the elastic material of only 1 in. long were used. These were firmly secured at one end to a small clip block, in which a light steel wire 12 in. long was screwed, the wire and spring in one line. This served as a steel-yard and indicator upon which weights were suspended. The free end of the spring was passed into a slit cut in an adjustable block of brass contained in a piece of tube 1½ in. in diameter, closed at the top and bottom, but having a passage in the side sufficiently wide to allow the introduction with free play of the wire and attached spring into the slit. A thermometer was slid down through the lid, with the bulb close to the spring, for indicating the temperature of the interior when heated by an external gas jet. The first experiment was with an inch of ordinary tempered watch spring; the end of the rod or pointer was very sensitive, and of course gave any desired range according to the weight attached. This was adjusted for a space of 6 in., which represented the extent of compression at which the temperature was applied. The four intervals from 100 deg. to 500 deg. caused deflections in the ratios of 13, 16, 40, and 52. The total heat deflection amounted to 2½ in.; the return when cool was ½ in., leaving 2 m., viz., the spring had become permanently deflected one-third of the range by the application of the last 500 deg. The second experiment with the same spring unaltered and ranging 6 in., presented a remarkable contrast. Starting again from 100 deg. with the same temperature as before, the corresponding ranges were in the space proportions of 3, 5, 9, and 15, at which last, or 500 deg., the deflection was only one-tenth of the compression instead of one-third as before; and on cooling, the spring returned so far that the permanent set was only two-tenths of an inch or one-thirtieth part of the primary range. The experiment repeated gave exactly the same result as to the proportionate distances of deflection, but the set became rather less. It may be questioned, however, whether this could be entirely eliminated by numerous repetitions, for a temperature of 500 deg. is sufficient permanently to impair the elasticity of steel springs. The next trial was with hard crown glass, as this method enabled thin threads of that substance to be used, having any desired degree of elasticity according to their tenuity. The end of a narrow strip one-tenth wide was drawn into a thread through a gas-flame, and the other end pointed to show the position on the indicating card. With this brittle material long sweeps could not be secured, the range of compression was only 1 in., with the same temperatures as for steel the deflection at 500 deg. was one-eighth of the compression, and the distance for each allotted temperature formed

about a similar irregular distance of division as for steel, with a permanent set in the same proportion, showing but little advantage in favor of glass as tested this way. An inch strip of strong hammered white metal, or German silver, was now tried, which by this operation had become exceedingly elastic, and was tested just the same way as the steel. This metal was very sensitive to the effects of heat, the first few degrees showing a visible drop of the index point. At 500 deg. the deflection amounted to just one-half the range of first compression, and on cooling, the permanent set was shown to be one-third of the same distance; but the remarkable distinction was that the divisions were nearly equal, the space at the last 500 deg. being the same as the first. This experiment was repeated with the now partly seasoned spring; the deflection for the extreme of 500 deg. was only one fifth of the range, having equal divisions as before, and the permanent set one-seventh of the same distance. Experiment third, deflection one-eleventh part of range, set one-eighteenth; fourth experiment, deflection one-eleventh, as in the last set, one twenty-seventh heat spaces, or divisions still equal. Such were the practical results of these trials, which, though sufficient to illustrate a condition, are not numerous or varied enough to establish a law. The author hopes to continue them under different circumstances, such as thin rods submitted to torsion with the test of heat at varying degrees of force. A comparison of numerous data might develop a definite law very useful to the practitioner in the various instruments to which it relates. The most singular result is that indicating that a metal whose elasticity is obtained by condensation of the material should lose it equally with equal degrees of heat, while steel, in which elasticity results from fire in the process of hardening and tempering, obeys a different rule. Possibly this may give some reason for the fact that a gold alloy has been used by some chronometer makers in lieu of steel balance-springs, probably rendering a secondary compensation less necessary. The author has seen such springs in use, but has never heard it stated why they have been applied. It is a long established fact that if a chronometer is adjusted for extreme temperatures it will be incorrect for mean ones, or the converse; and to meet the irregular way in which the elasticity of steel is affected by heat, this law of elasticity in relation to temperature, once ascertained, might determine the path in which the compensating weight should traverse, so that a due proportionate decrease of central force might counteract the elastic loss of the spring by increase of temperature. The author must state that the indications with glass were far less definite; but to demonstrate how great and sudden changes of temperature may affect a thermometer the following experiment was tried:—The bulb of a thermometer was suddenly plunged into melted lead; the mercury instantly darted down far below zero; the action was so quick that the point could not be ascertained. This was caused by the sudden expansion of the bulb by heat before it reached the mercury by conduction; this then began to rise very rapidly, and before it had arrived at the top of the tube the bulb was withdrawn. This requires adroitness, for, as we all know, the instant that the mercury touches the top the bulb will burst. This must be greased before immersion in the fused lead, otherwise a film of the metal will adhere and retain sufficient heat to carry the mercury to the top, with a consequent fracture. A thermometer treated in this rough manner afterwards showed an index error of six degrees, the mercury having risen to this extent; but after a few days the equilibrium was partly restored, and the error remained permanently at 3 deg.

As a comment on the above experiments it may be urged that a source of inaccuracy would arise from a vertical force acting on a lever varying in length, but after the deflecting weights were suspended the arm was brought so far above the horizontal line as to divide the remaining small arc due to the heat deflection. The sine of the chord for this in a radius of 12 in. was too minute to make any difference in the force of leverage worth noting.

Further experiments are required, but the present ones show directly in all instruments for indicating and registering weight, pressure, temperature, and perhaps, time, by means of the law of elasticity, that the material, whether of steel, glass, and particularly any metal in which this property is obtained by condensation or hammering, the importance of subjecting them to an excess of temperature before the graduations and adjustments are made.

PROPORTIONS OF PINS USED IN BRIDGES.

Communication from C. H. BENDER, C. E., to the "Railroad Gazette"

Your edition of November 1st contains a criticism on my paper referring to proportions of pins used in bridges, which was published in "Van Nostrand's Magazine," and reprinted as a little volume of Van Nostrand's "Science Series."

The said criticism I believed not to be one likely to give a just or even correct abstract of the paper, and therefore in the following I wish to make a few remarks towards defending my investigations:

The paper consists of three parts, of which the first intends to furnish a "sufficient" idea of the differences between maximum and minimum pressure exerted on the bearing surface of a pin. The second analyzes the shearing strains acting in the cross-sections of the pins; while the third one refers to the maximum tensile strains caused by flexure. This last part is the one by which the dimensions actually are determined, and forms the centre of the investigations, since the two previous ones are only secondary in their importance.

The experimental researches of the English engineers had failed to recognize the influence of the thickness of the eye-bar on the strength of the joint. Experiments had been made with wide and thin eye-bars, and from these a general rule had been derived, thought to be correct for all kinds of bars, fixing the diameters at $\frac{2}{3}$ or $\frac{3}{4}$ of the width of the bars. This rule in more than one case has caused misapplications by which the joints were built by far too weak, and on page 47 of this little book, in a couple of rough examples, it has been shown what great danger there lies in the use of this rule. The series of diameters finally adopted in this little book, for a number of forms of bars, only for very flat bars approaches those obtained with the English rule; while for bars as they are generally used in well-designed American bridges much greater diameters had been found.

American bridges in principle differ from those used in Europe by not giving up that most direct mode of forming joints which had been in use previously to the time when the English engineers introduced the rivet, since which the pin connection has been abandoned by the majority of English engineers. The establishment of the practicability of wrought iron bridges with rivet connections, in consequence of the success of the Britannia Bridge, had led Europeans in a channel from which only very lately and in consequence of the American success with pin connections—thus far only in Germany—they have commenced to return; while the insufficient success of badly-proportioned pin-bridges, especially in England, still holds in captivity the judgment of a great number of European engineers.

The importance of a careful study and of proper porportions of pin connections is therefore most obvious, and it was the recognition of this fact which led me to the somewhat intricate and time-absorbing investigation, the results of which were condensed in the little book published by Mr. Van Nostrand. It is admitted that not all of its contents are of an elementary character, but that it requires some study, and that it supposes familiarity with the higher theory of elasticity up to its present level.

I am charged with an unlimited confidence in the theory. No mistake could be greater than this. The little book itself contains the strongest proofs against such assertion, and these, strange enough, are quoted in the criticisms. Thus, on page 15, proper experiments are desired to determine the influence of play in pin holes, which was expressly stated on pages 5, 6 and 15 not to have been drawn into calculation, and whose introduction would have led to much greater differences of pressure, and also to greater diameter than those found under the adopted suppositions. On page 40 I have again stated the necessity of proper experiments in order to determine the durability of forged, riveted or machine-worked parts for each class of materials.

We have but lately commenced to arrive at some reliable ideas as to the real value of the material of construction. The gentleman to whom I must consider to be due the greatest thanks in this respect is Mr. Woehler, some of whose experimental results are quoted on page 38 of the little book. The reason why this gentleman was more successful than others lies in the circumstance that he is at the same time as well versed in the theory of elasticity up to its higher branches as he is a practical mechanical engineer of great experience. In order to make successful experiments,

before all it is necessary to know what should be experimented on, and in a good many cases the elementary school knowledge is not sufficient to this end. The investigation, therefore, should precede the experiment, and not follow, as the author of the criticism asserts. If this critic does not place much reliance in the theoretical deductions of the character furnished year by year in voluminous books, he will find myself to agree with him perfectly. These are filled with an enormous amount of mathematical rubbish, and contain generally nothing but a great and uselesss quantity of common algebraic labor, which could readily be dispensed with. Theory of this class, indeed, has done a great deal of mischief. But it would be unjust to declare that it has caused all the numerous failures on account of following theories in "untried cases." Just as many grave errors have been caused by improper experiments, which are generally accepted with considerably less hesitation, and without the necessary examination of their suppositions.

On pages 16 to 24 of my paper I believe that I have clearly and conclusively proved that all those experiments which have reference to pins were not made in accordance with the wants of practice, and that its very results have led to misapplications.

I will add here something more concerning deluding experiments. The English experimenters believed that they had established that the modulus of elasticity of wrought iron was pretty nearly a constant value. But, on the contrary, the moduli of elasticity of wrought iron, on authority of experiments on many thousand eye bars, now members of bridges, are varying from 18,000,000 to 45,000,000 lbs. per sq. in. The supposition of a constant value of the modulus forms the important basis of the theory of continuous beams, which falls to the ground with that supposition. The proportions of the Britannia and the numerous other continuous bridges, therefore, cannot be considered as correct.

The connections of all European bridges are based on the results of experiments on a small scale on riveting, which for many reasons can be proved not reliable under the present practice. The results of such practice are apparent enough. Thus, for instance, riveted girders built according to those rules and arranged for actual use on the "Chemin de Fer du Midi," in France, when tested broke under 26,000 to 27,000 lbs. per sq. in. They deflected, inside of the elastic limit, three times as much as might have been expected from a theoretically perfect girder. The deflections of the Conway Bridge show a decrease of from 25 to 42 per cent. of the modulus of the iron used, proving again that the empirical rules derived from experiments on rivets made up to the ultimate strength did not give the expected results when tried in a manner nearly in accordance with the practical use.

The same insufficient result was obtained by Brunel's tests of a 66-ft. long plate girder, which broke under the calculated strain of 30,000 lbs. per sq. in. of net area. Also the experiments on pillars of the often-quoted English engineer Hodgkinson by American tests have been proved to be totally unreliable. (Compare Mr. Samuel Reeves' experiments on his columns.)

In my paper I have repeatedly pointed at the necessity of making experiments which will be congruous with the state of affairs in practice. Nobody would test a piece of cloth by putting it to its ultimate strength in a machine, for there are numerous other conditions to be filled in order to make a good and durable coat. And yet such a rough course is taken when it comes to try the qualities of a material of construction.

The author of the criticism, therefore, makes a too sweeping assertion when he thinks that experiments on the ultimate strength "at least seem to indicate the weakest part of a member or to indicate in what direction the correction should be made." As long as the experiment is analogous to the usage of the member, this is true; but there is nothing to prove that it must be so when the member is quite differently used. (With reference to pins, compare pages 23 and 24 of the little book.) Thus, for instance, Hodgkinson's experiments on compression to the ultimate strength seemed to prove that with compression lies the weak point of wrought iron, while, on the contrary, numerous experiments on impact prove that under repeated strains lower than the ultimate strength the tensile parts give way previous to the compression members. This is probably the same reason why bridges with cast-iron compression members in this country when failing did so by rupture of the tensile parts.

The author of the criticism also thinks it

quite obvious that the pins should have been made strong enough, while there is supposed to have been great difficulty in bringing the eyes to the proper proportions. From what we know at present, this seems plausible enough; but actually it was not so. The engineers thought they could save metal by reducing the diameters of pins, proofs of which are the failure of the Crumlin Viaduct as first designed, and the failures and wearing out of many chain bridges.

Again, I did not think it worth while in my paper to speak about the very small and unimportant deviations of the elastic law inside of what is called the elastic limit, which is nothing but a harmless name, meaning the limit where those deviations commence to be of any importance, even in theory.

It is not a mere phrase when I asserted that the theory within the elastic limit is not less correct than the law of gravitation applied to the movement of planets. A very strong foundation for this assertion can be found on pages 38 to 41 of the little book.

Purely theoretical investigations, based on the general law of elasticity, under application of the very finest and most elegant analysis, have led Navier and others to conclude that each direct strain in any direction of a body must be accompanied with a negative direct strain one-fourth as strong as the first, but acting normally to it. By a series of not less acute conclusions, this law leads to the other, that the modulus of shearing elasticity is only two-fifths of the modulus of direct tensile or compressive elasticity, both of which in wrought iron and steel of good make are equal. Most interesting experiments of Regnauld and Wertheim have—notwithstanding the technical difficulties—proved that this law for wrought iron is correct within 1½ per cent. (See page 35.)

Mr. Waehler has determined the true moduli for good iron and steel directly by tensile, transverse, and torsional experiments, and finds the ratio between both to be 0.39, while the theory gave 0.40. This is certainly a most satisfactory result. He has done more. He has tried the durability of iron and steel under impacts, exposing the materials to exertions of the same kind as is the case with railway car axles, and as is the case in bridges, and thus he found that torsional or shearing strains cannot be withstood as high as direct strains, and that the ratio of durability under both kinds of strains is as 0.793 to 1,000, while theory gives 0.800 to 1,000.

Now I do not deny that I hold this victory of the theory to be just as beautiful as the once so surprising confirmation of the law of gravity by the discovery of a previously calculated planet.

The question really at stake here is this: Are we at liberty to apply the established theory of flexure of plain beams to the calculation of the strains acting on bridge-pins? Relying on the confirmation of this theory by a most abundant number of well-conducted experiments on transverse strains, I answer this question with a decided yes, so much the more since a pin—as stated on page 46 of the little book—is a piece of iron unimpaired by workmanship and fire. Certainly this is admissible a hundredfold more than the application of the theory to the punched and riveted compound beams, girders and bridges, of varying sections, depths, moduli, etc. In the criticism I do not find any doubt as to the application of the elementary theory of flexure to the determination of the maximum tension of a pin, by which the diameters actually were determined (from page 42 to 47), and whose results do satisfactorily coincide with the best present practice, nor has any fault been found with the second part of the paper.

The suspicion which is thrown on the usefulness of my labors only refers to its first part, which is the least important of the three, and has only for its purpose to give a sufficient idea of the distribution of the pressure over the pin-bearing, under the expressly stated supposition that no friction is taken into account, and that the pin accurately fits the hole. It is also expressly stated that under this supposition the diameter of the pin would be found a little too small.

Under this supposition the pressure on the semi-surface of a transverse slice of a pin is actually uniformly distributed over the diameter, and, if it were not so, it would only be necessary to determine the ratio between the maximum and minimum pressures on the bearing surface.

The deviation of the maximum pressure found under my supposition from that of a pin with play could not be unknown to me, since, as far as I could find, my teacher, Professor Grashaf, about a dozen years ago,

was the first who made similar investigations toward the determination of the proper diameter of expansion rollers used in bridges.

When the critic says that on page 6 the assumption of uniform transverse shearing stress underlies my analysis, there must certainly exist a misunderstanding, and he means to say that the pressure on the semi-circumference of a bearing circle is supposed to be uniformly distributed over the diameter.

There is also a misunderstanding on the part of the critic when he thinks that I had proved that there is no shearing strain on the surface of the pin. In fact, there is but one point of the circumference of a section through a bearing-pin which is free from shearing strain.

Again, it is objected and said that in order that the transverse shearing should be uniformly distributed, the pin must fit the bearings. This remark is not correct; for even when the pin does fit exactly, the shearing strain will not be uniformly distributed. Again, shearing strain and pressure were substituted one for the other.

In the investigation under No. 1 of the little book, one part of the theory has not been taken up at all, and this is not noticed in the criticism: namely, the deflection of the pin due to the shearing strain. By this the maximum pressure on the bearing surface would have been found greater, but the amount can practically be considered as offset by the relief caused by the longitudinal pressure due to flexure. Namely, in the criticism doubt is expressed as to how the maximum pressure is—if at all—modified by the tension of flexure above. This tension, indeed, is without influence, but not so the longitudinal pressure below, which, according to Navier's law (see page 34) causes a vertical tension, which reduces the pressure.

Under all circumstances, the diameter of pins found, under the suppositions of the little book (page 6), would be theoretically too small, when the pin does not fit exactly, and the given dimensions therefore must be considered as minima.

Finally, it may be allowed to add, in answer to one other remark of the criticism, that the influence of the transverse stiffness of the long and thin eye-bars is practically too small to be considered in the calculation; and since there are so many irregularities of manufacture, this little assistance is but too welcome.

On the whole, it is believed that notwithstanding the difficulties of exact examination of even the very simplest phenomena of elasticity, the first part of my investigation has at least done this good—that of giving to many an idea that the bearing pressure is not at all uniformly distributed over the cross-section; that even with diameters of pins as large as those given, we still have to deal with pressures probably as high as 15,000, and even 18,000 lbs. per sq. in., according to the more or less high degree of perfection of manufacture.

If I could hope by my paper to have caused a number of experiments to be made on this subject, such as recommended on page 15, the labor spent on this investigation I would consider as well recompensed.

EXPLOSIVE COMPOUNDS.

From "Engineering."

MM. Roux and Sarran, engineers to the Government department in France for the manufacture of gunpowder, have recently made experiments on the pressure of the gas liberated by the combustion of various explosives. Applying the well known laws of Mariotte and Gay Lussac to these experiments, they ascertained the volume of the gaseous products reduced to 0 deg. Cent., and a barometrical pressure of 0.76 metre, or 30 in. English. The apparatus they employed was an eprouvette, of a cylindrical shape, made from forged iron. and having an internal diameter of 0.022 metre, and 0.3 metre in height. This eprouvette, in which the combustion of the powder was effected, was closed at one of its extremities by a screw-tap, traversed by an insulated wire, which was employed for the purpose of igniting the explosive under examination, and furnished, at the other extremity, with an adjutage, screwed into the socket of a manometer. This manometer has a differential piston, the pressure exerted on the small base (of which the area equals $\frac{1}{100}$ of the larger base) of the piston being measured by that exerted on a larger base by a column of mercury, reduced in the proportion of the two ba-es, and expressed in millimetres. A known weight of powder

being placed in the eprouvette and ignited, the mercury rises quickly in the tube of the manometer, but as quickly falls as the temperature of the produced gas is reduced, and gains, after an interval of four or five minutes, a stationary position, which it retains for several hours with scarcely perceptible change. The temperature of the disengaged gas is then similar to that of the surrounding atmosphere. The manometrical height, as observed, multiplied by 100, gives the pressure. The following gives the elements of one of the determinations of experiments on powder used for charging cannon. The pressure of gas produced by 3, 4, or 5 grammes respectively at 27 deg. Cent., gave a height of 64.0, 86.5, and 10.6 millimetres of mercury. Reducing these results for 1 gramme, the respective heights of the mercurial column will be 21.3, 21.6, and 21.2 millimetres, giving a mean of 21.4 millimetres, with a range of 1 per cent.

The capacity of the eprouvette being 0.102 decimetre cube, the volume at 0 deg., and the pressure at 0.760 metre of mercury (30 in. English) of the gas produced by 1 gramme of powder, is arrived at by the formula:

$$\text{Vol.} = 0.102 \frac{214 \times 273}{76 \times (273 + 27)} = 0.271 \text{ cub. dec.}$$

The results obtained by experimenting on different kinds of powder, taking into account the amount of heat produced by the explosion, afford the following table:

Kind of Powder Used.	Calories developed.	Permanent volume in litres of gas produced by 1 kilogramme reduced to 0 deg. Cent., and 30 in. of mercury.	Pressure in atmospheres.	Maximum effective work in ton-metres.
1.	2.	3.	4.	5.
Fine sporting	807 8	4654	3989	373
Common powder	752.9	4360	4168	349
Gunpowder called BB	730 8	4231	4339	339
Commercial	694 2	4042	4160	324
Ordinary mining	570.2	3372	3792	270

The results given in column 2 were obtained by the calorimeter, and represent the heat disengaged by the products of combustion of 1 kilog. or 2.2 lb. avordupois, English, of powder passing from the temperature of combustion to that of the external atmosphere. Taking into account the coefficient of the specific heat as the volume of gas produced by the combustion of the powder, it is possible to deduce the temperatures of combustion. According to this calculation they vary from 3,300 to 4,700 deg. Cent.; but considerable uncertainty attends such results, owing to the inexactitude which the various circumstances introduce into the experiments.

The pressures given in the fourth column are calculated by an application of the laws of Mariotte and Gay Lussac to the volume and temperature of the gaseous results of combustion. But as these hypotheses require modification, the results in this column must be considered as relative rather than exact. In column 5 the amount of work, expressed in ton-metres, afforded by the liberated gases, is given, this amount being the mechanical equivalent of the heat liberated.

MM. Roux and Sarran have carried on experiments with the same apparatus on other explosive compounds; but in these series of trials there were circumstances that vitiated the results—as, for example, the length of time before the final condition of the experiment occurs. The following table gives some particulars of the experiments:

Explosive Tested.	Calories disengaged by 1 kilogramme.	Weight of gas per kilogramme.	Reduced volume of as per kilog.
Gun-cotton	1056	0 853	720
Dynamite with 75 per cent. of nitro-glycerine	1290	0.600	455
Picrate of potash	787	0.740	576
Mixture of 50 per cent. of picrate of potash and nitre	916	0.485	334
Mixture of equal weights of picrate and chlorate of potash	1180	0.466	329

The results of these experiments are of great interest both for artillery and industrial purposes, especially in regard to mining operations. They are equally interesting as a branch of philosophical research which may give rise to further applications of great practical value.

FIRE-PROOF FLOORING AND FIRE-PROOF CONSTRUCTION.*

By LEWIS HORNBLOWER.*

From "The Building News."

The question of fire-proof flooring and fire-proof construction generally has for a long time occupied my attention, and was brought more forcibly to my mind by the gigantic fires that have occurred, not only in America, but in our own country. The loss of life, to say nothing of the loss of property, has been enormous, and the insurance offices have suffered considerably. I find, from a return made to the Board of Trade for the year 1871, that the losses of thirty-five insurance companies amounted in that year alone to the enormous sum of £2,197,004 14s. 3d., and this fearful loss has occurred notwithstanding all the advantages of the so-called fire-proof construction at present in practical use.

All descriptions of supposed fire-proof construction hitherto invented have miserably failed; iron girders and iron columns supporting brick vaulting have alike proved ineffective, and when subjected to great heat have collapsed. Professor Lewis, F. S. A. in a paper read before the General Conference of Architects, in 1871, states:—"The real difficulties of fire-proof construction begin where there is a large mass of combustible materials, as in warehouses and similar structures. In these the heat developed is something which an ordinary observer would scarcely credit. I exhibit some specimens of brass and iron nearly in a melted state, showing that the temperature which they had failed to withstand must have been some 2000 deg. Fahr.; the whole place, in fact, must have been a glowing furnace." The only structures that have successfully resisted the most intense fires, and remained firm and rigid during their continuance, have been floors of brick, stone, or tile carried on brick vaulting, supported on brick piers. This method of construction has great disadvantages, from the great amount of space occupied by the brick piers. The desideratum to be aimed at is the construction of a perfectly fire-proof floor capable of covering a large area unsupported by columns and girders of iron, which, at the same time, must possess carrying power to sustain heavy loads of merchandise, and also admit of carrying fire-proof division walls for separating the rooms on the upper stories of large public buildings, as, for instance, hotels, hospitals, private houses, etc.

My attention was more particularly drawn to this question at the Congress of Architects of Great Britain and Ireland, called together by the President and Fellows of the Royal Institute of British Architects, in May, 1871. I took considerable interest in the discussion that ensued, and determined, if possible, to invent a flooring that would be fire-proof. After many experiments I at last hit upon a flooring that combines all the qualities requisite to insure perfect security from fire, as well as enormous carrying power.

It was admitted by Mr. Aitchison, the architect for the S. Katharine's Dock Company, who had constructed a large number of warehouses for that Company, that iron columns supporting iron girders are not fire-proof, and that in cases where large fires had occurred, the girders and columns either melted from the intense heat, or cracked and collapsed the moment cold water from the fire-engines played upon them. Mr. Robert W. Edis, F. S. A., in a paper read before the General Conference of Architects, held in London, May, 1872, in "Notes on the Late Fires in Paris, May, 1871," states, with reference to the so-called fire-proof construction in use in that city:—"That the utter uselessness of stone construction to resist the action of fire is no new story; but those who were at all incredulous as to the reason or truth of this will, I imagine, be convinced by the entire failure throughout of the so-called fire-proof construction in all the fires in Paris." "Of wrought and cast iron as used in floors and roofs, the same remarks will apply as to their fire-proof capacity; both failed lamentably; and although the iron work did not of itself add fuel to the flames, as a general rule, it did much more damage by breaking and snapping, twisting and turning, than any wood construction could possibly have done. It was extraordinary to notice the eccentric forms into which the wrought-iron roofs—notice especially the roof over the Salle des Pas Perdus in the Palais de Justice—had been twisted; wrought-iron gir-

* A paper read before the Liverpool Architectural Society.

ders of immense size were turned about by the flames like ribbon, and must in many cases have been heated to almost fusing point."

Captain Shaw, the energetic and intelligent Chief of the London Fire Brigade, stated at the Conference that his men absolutely dreaded trusting themselves on floors supported by iron columns and girders; that they have no confidence in stone staircases tailed into the side walls; but would have greater confidence in staircases of timber plastered on the underside, or in wooden floors supported on girders of timber, which, although subject to the action of fire, yet, at all events, gave the fireman some slight warning before succumbing to the devouring element. Seeing, from the mass of evidence produced, that iron and stone constructions are not fire-proof, and not to be depended upon, I directed my attention to a combination of fire-clay tiles and Portland cement concrete. It was necessary in this combination to use some small portion of iron as a tie, but I have used as little of this material as possible, and have placed it in such a position that no fire can touch it, or if it did, the effect would be harmless.

The object and scope of the invention is to provide walls, partitions, floors, and roofs of buildings at once light, cheap, durable, thoroughly fire-proof and convenient for ventilating the rooms or spaces they enclose. For these purposes I employ the materials hereafter named, in combination, for walls, partitions, floors, and roofs: iron or steel, hollow earthenware and cement concrete; and for partitions, under a modification—iron or steel, metal wire, earthenware pipes, and cement concrete.

Walls, partitions, floors, and roofs are constructed of sheet iron or steel, preferably so formed as to represent one-half of an octagonal honeycomb cell in transverse section, reversed and placed as flitches parallel to each other, with a space of 6 in. between the flitches. In this space are placed pipes of hollow earthenware, with the sides splaying outwards at the base to form a skewback. These pipes are in 2 ft. lengths, and the iron flitches are bolted to and through the earthenware pipes, thus forming a composite girder. These girders are placed 2 ft. from centre to centre at the proposed ceiling height, having 4½-in. wall-hold at each end. A rough staging is required by way of support on which to lay the floors; between each skewback an earthenware hollow pipe—with oval-shaped head and flat soffit, with a dovetailed channel or indentation running longitudinally to receive plaster of ceiling—is placed, with sufficient room left between the composite girders to receive the charge of cement concrete. This is filled in from the upper side and well consolidated. The upper surface of floor is truly levelled and grouted with pure cement grout, and brought to a fair and smooth surface, if intended to form a finished floor; but if tiles, marble, flooring boards, or parquetry, are proposed to be used for finishing flooring, the concrete is simply levelled and left rough to receive the battens to which the boarded floors are nailed.

Holes are left in the soffits of the hollow pipes, where requisite, for ventilating the rooms below, and the pipes so utilized are connected with flues in the walls adjoining; or if it is desired, in these days of dear coal, to economize fuel, hot air may be conveyed, by means of these hollow tubes, from any central and convenient point in the basement, where a heating apparatus may be located, to any room throughout the building thus constructed.

In walls and partitions the iron and steel lengths are placed in a vertical, in floors in a horizontal, and in roofs in an angular position.

Partitions are constructed of half-octagonal honeycomb iron or steel cells, with metal wire stretched across, instead of laths, to receive the cement concrete or plaster, such wire serving to tie the iron and steel lengths, and at the same time to hold and strengthen the cement concrete or plaster. It will be obvious that bricks, flooring boards, tiles, marble, or other material or desired surfaces, may be attached to parts constructed in accordance with my invention, whether for floors, walls, ceilings, or roofs. I am satisfied that this is the only really fire-proof construction now before the public, and by far the cheapest.

In consequence of the extraordinary advance in the price of iron, I have been compelled, in order to keep down the cost of the floor, to economize in the use of wrought iron in its construction. I can now construct a floor without the octagonal iron flitches, simply by forming the composite girders separately, before fixing, by running a $\frac{5}{8}$ or larger diameter wrought-iron rod or bar, with nuts, head, and screws,

through the centre of the hollow tiles, and charging the interior with fine cement concrete, gauged 4 to 1, and screwing the whole together, thus making a continuous beam and skewbacks to receive the hollow oval earthenware centres, which, in fact, throw the whole construction into a series of small arches, supported on composite girders, bound into a homogeneous mass by the cement concrete.

This mode of construction has many advantages for cottages either built separately (self-contained) or in accordance with the Scotch plan, where a number of dwellings are collected in flats, having access from a general staircase. It is cleanly, harbors no vermin, commands a ready means of ventilation—so necessary to the health and comfort of all, and so often unattainable by the poor—and would not entail constant repairing.

This construction would be of immense importance if used in the erection of hospitals, dispensaries, barracks, cotton manufactories, breweries, railway stations, warehouses, drying sheds, malt rooms, etc. It would be very valuable if used in the construction of floors over lock-up shops—so common in London, and in which, unhappily, so many fires have occurred, caused, I am informed by the police, in too many cases by fraudulent tradesmen who purposely set fire to their shops to rob the insurance companies, without any consideration for the unfortunate families that may be living above them. One great commendation is that it is cheap, and can be constructed by any laborer of ordinary intelligence.

Great care must be taken in thoroughly incorporating and amalgamating the materials forming the concrete together—old bricks, broken small enough to pass through an inch mesh, well-washed gravel and sand. Furnace slag, broken as before described, makes an excellent material to mix with the Portland cement to form the concrete. The proportions should be accurately measured; six, and (if the ballast is sharp and good) sometimes seven, of the materials above mentioned to one of the best double-tested Portland cement, carefully turned over twice while in a dry state, and well mixed. Too much water is fatal to the setting qualities of the concrete, because, when applied too copiously, it only washes away the cement from the mass; just sufficient water should be used to temper the whole, and the best mode of application is by a rose waterpot. The concrete should not be made in greater quantities than can be readily carried to the floors and used before it commences to set. In forming the floors this fact must be strongly borne in mind. The floor must not be constructed in layers, but the full thickness must be put in in one body; therefore no more should be attempted at once than can be satisfactorily completed the same day. When the floor has set for a fortnight the platform may be struck, but as the material gains strength daily until crystallization is complete, the floors should not be too heavily taxed at first.

The partitions, I am satisfied, would be very valuable if used instead of the stiled partitions, so generally used now to divide the rooms on upper floors—in fact, nearly all the internal divisions of London houses are simply constructions of timber. The weight of the partitions could be suspended by tension rods from the floors above, thus dividing the weight throughout the structure.

For cottages and smaller house partitions of 4 in. and even 3 in. thick would be ample. I embed the metal uprights in concrete, passing the rods through the pipes, as before described.

Now as to the carrying power of these floors. By practical experiment I have tested them in this particular. One specimen had a bearing of 7 ft. 6 in. between supports, with 3-in. wall hold at each end (this was tested simply as a beam of that breadth, not as a floor, which would have had the additional counteracting force of equilibrium to have aided it), and 14 ft. long. After giving it 18 days to set, the supports were removed, and it was loaded with 31 tons of dead weight, or 3½ tons to the yard superficial. Another specimen had a bearing of 15 ft. 6 in. between supports, with 3 in. wall hold at each end. After allowing it twenty-one days to set, it was loaded with 6 tons of dead weight in the centre, equal to a load equally distributed of 1 ton per superficial yard.

It has been very clearly shown by the experiments of Mr. John Grant, C. E., that Portland cement concrete does not attain its full tensile strength for years, the material gaining at the end of one year over 4 times the strength it possessed one month after construction; consequently, the bearing power of the latter specimen would be after

one year about 48 tons distributed over the entire surface, or upwards of 4 tons to the superficial yard.

In addition to the flooring, I have invented a very simple method of rendering iron columns and girders already erected in buildings perfectly fire-proof, by means of a ring of fire-clay tubes attached to the periphery of the columns and soffits and sides of the girders, securely bound together and attached to the iron by Portland cement concrete, which allows of a free current of air between the iron and external facing of concrete. This casing adds only 2 in. to the thickness of the ring of the metal column.

I have refrained from bringing this matter before the public until I had proved its capabilities. I have had an opportunity of testing this practically and thoroughly in numerous buildings lately erected by me on this principle, in Cumberland, for the Directors of the Hodbarrow Mining Company. The spans I have covered have been 14 ft., but I can readily, and should not hesitate to carry a floor over a span of 22 or 24 ft., without any other support than that derived from the walls themselves, by increasing the depth of the composite girders.

These houses, 58 in number, in which I am introducing my patent flooring, are to be seen at Haverigg, in Cumberland. The material that is used for floors and roofs is simply sea-beach shingle combined with Portland cement. In the construction of the walls I have used the proportion of 8 of shingle to 1 of cement, and for the floors 6 to 1 of the same materials respectively, but am satisfied that in the larger proportion of 8 to 1 it would be equally satisfactory.

Concrete walls (and I speak from actual experience) of 9 in. in thickness, will bear as much as any 14 in. walls built of brick. It is superior in many respects; it is impervious to water, and the walls can be built by any ordinary laborer, under proper supervision.

With respect to the floor, it has greater carrying power than any flooring in existence, while the whole of the intermediate hollow space can be utilized.

The weight of the floor is 6 cwt. to the yard superficial, but this may be made less by reducing the depth of concrete on the floor. This invention is as useful for roofs as floors, it being only necessary to give a slight shedding towards the gutters. A good deal, however, depends upon the genuineness of the cement used; it must be equal in quality and well tested as to strength. In the floors that I have constructed I have used the very best Portland cement. I also tried some cement made at Bebington, in Cheshire. I had these cements tested in bars 2 ft. long by 2 in. square; weights were applied in the centre; each bar had a bearing of $\frac{3}{4}$ in. at each end after being made a fortnight. The Bebington cement broke with 97 lbs. weight, while the London cement only stood 49 lbs. I am informed that the component parts of the Liverpool cement are Welsh hydraulic lime and the clay silt of the Mersey; the London cement, chalk lime and the clay silt of the Medway. Of course they both undergo similar manipulation in the manufacture.

I think I may safely lay claim to the following advantages embraced in my invention:

1st. Great cheapness.

2d. Large carrying power.

3d. Less iron (and that carefully protected) being used in the construction, and the other materials used being perfectly uninflammable, its fire-proof qualities must necessarily be superior to those of any other flooring.

4th. In ordinary fire-proof floorings columns and girders of iron have to be used, placed at intervals varying from 8 ft. to 12 ft. apart, and these are totally unprotected from the action of fire. In this flooring, even for heavy warehouses, girders would be required 15 ft. or 16 ft. apart, and columns 20 ft. distance, and these are carefully encased with fire-proof material; thus, not only saving a large amount of expense in girders and columns, but giving the floors, even in the hottest fires, by calculation, at least six hours' grace (as compared with ordinary uncased columns and girders) before the columns would become red-hot; then, when water is played upon them, the casing would protect the columns and girders from the unerring action of the contact of the two elements, and enable them to cool down gradually.

5th. No ceiling joists or laths are required, the soffits of the fire-clay tubes being grooved and dovetailed to form key for plaster.

6th. The excellent opportunity given, where the floor is used, of conveying hot air to, or foul air from, the various apartments in which it is laid by means of the

hollow fire-clay tubes; and this is of greater importance to the housekeeper since the great advance in the price of fuel, for here a great economy can be effected.

7th. In this construction I can observe no perceptible lateral thrust—the strain is all vertical.

8th. No harbor for vermin.

9th. No counterceiling required.

10th. The boarded floors need not be laid until all the plastering is finished.

Before going into the question of fire-proof flooring I thought it desirable to examine what had already been done in this particular. I therefore went carefully over the lists of patents, and derived no little amusement in the search. I thoroughly examined 317 separate patents. Many of these have secured provisional protection only; some refer to rendering buildings certainly water-proof, and partially fire-resisting only. During the last 240 years the subject of fire-proof construction has occupied the attention of our profession.

The earliest patent was granted to one Deekins Bull, 33 years before the great fire in London, viz. in 1633. It was granted by His Majesty Charles I., by the Grace of God King of England, Scotland, France, and Ireland.

TESTS OF STEEL.*

By A. L. HOLLEY, of Brooklyn, N. Y.

From "The Engineering and Mining Journal."

The intention of this paper is not to discuss this important subject in all its bearings, but merely to point out why mechanical tests of steel, as ordinarily made, are not, alone, of any special value to engineers—certainly not to general mechanical engineers.

The agents of the Barrow Hematite Steel Company, one of the largest and most successful Bessemer establishments in England, have recently distributed a report, made by Sir William Fairbairn, on the transverse, tensile, and compressive resistances of certain bars of this steel. The number of tests is very large; they seem to be careful and minute; and the modulus of elasticity, the work up to the limit of elasticity, and the limit of working strength, are fully tabulated according to the latest formulæ.

This is very well—indeed, it is indispensable, as far as it goes; but it goes no further than to inform the ordinary engineer that there is an unknown substance which possesses these physical properties. As to what the substance is, the report gives him no working knowledge, for not a single analysis is given of any of the bars tested. The most that is said of some of them is that they are either "hard" or "soft," which is sufficiently evident from the experiments. "A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk." To the engineer who wants steel for a specific purpose, it gives only the faintest clue, to say that steel is hard or soft. There are a dozen grades of both hard and soft steel, adopted to different purposes. Rail steel is soft, and boiler-plate steel is soft, as compared with many structural steels, and with the whole range of spring and tool steels; but the one perfectly adapted to rails would be useless for boilers.

In order that engineers may know what to specify, and that manufacturers may know not only what to make, but how to compound and temper it, the leading ingredients of each grade of steel must be known. Pure iron would be unfit for nearly all structural purposes. Upon the substances associated with it depend its hardness, malleability, stiffness, toughness, elasticity, tempering qualities, and adaptations to various structural uses. These ingredients are, indeed, impurities, but the term "impurity" unfortunately implies a defect, whereas the thing may really impart the essential quality. All the usual ingredients give what is called "body" to steel. Carbon, within specific limits, as is well known, gives hardness, elasticity, resistance to statical strains, and tempering qualities. Under certain conditions of composition it even gives resistance to sudden strains. Manganese (and this fact, by the way, is not so generally known) gives, in different proportions, hardness, toughness, malleability and elasticity. Chromium imparts

* A paper read before the American Institute of Mining Engineers, at Easton, Pa., Oct. 22, 1873.

similar qualities, but to what precise extent we do not know, in default of a proper comparison of chemical and mechanical tests. Silicon, although considered a bane by steel makers generally, and, singularly enough, advertised as the great panacea for the weaknesses of steel by certain modern inventors, has probably, in proper proportions, a healthful influence on the physical properties of steel. Even phosphorus, the arch enemy of the Bessemer and open hearth manufacturers, may in some degree be a valuable ingredient.

Whether or not certain foreign substances, which, separately added, produce similar results, would produce a better result if combined in certain proportions—for instance, whether carbon alone in any degree, or silicon alone in any degree, would make as good a steel for certain uses as carbon and silicon combined, it is, in default of proper experiments, impossible to state. The probability is, that there is a proportion of carbon and manganese which would give the highest possible value to all structural steels. We formerly added spiegeleisen to decarburized Bessemer metal solely to impart manganese to the oxygen of the oxide of iron formed in the Bessemer process. We now add a larger proportion of spiegeleisen, not only to remove the oxygen, but also to mix manganese with the steel. And we think we find that if the proportions of silicon and phosphorus are sufficiently low, and carbon does not exceed $\frac{1}{2}$ of 1 per cent., manganese to the amount of $\frac{3}{4}$ of 1 per cent gives the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails, which no proportion of either carbon or manganese, not associated, can impart.

When we consider that $\frac{2}{10}$ or $\frac{3}{10}$ of 1 per cent., and in some cases a fraction of $\frac{1}{10}$ of 1 per cent. of foreign metals, will change the character of steel in a high degree, and when we farther consider that the physical results of these combinations have never been tested or analyzed in any thorough and comprehensive manner, we may well reiterate the common expression that the iron and steel manufacture is in its infancy.

But it is not necessarily in its infancy. We simply do not develop it. The general complaint of engineers and machinists is, that they occasionally get, but can never get regularly, the precise quality of steel they require; and yet it is probable that thousands of tons of steel have been made which are suitable for each of these purposes, but have been used for others, and that the precise grade required in every case could be reproduced by the 10,000 tons. The trouble is that neither the user nor the maker knows what the material is. They have put no mark on it by which they can recognize it; they have kept no recipe. All they can do is to use ingredients of the same name, and approximately the same quality, and to guess at the physical properties of the product, aided by such crude tests as can be made during manufacture. Mr. Wm. H. Barlow, in a late address on modern steel before the British Association, says that one reason why steel is not more used for structural purposes is, that the metal is of various qualities, "and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality." But neither Mr. Barlow, nor any of his associates in Government experiments, proposes the true solution of the difficulty. It is no more necessary to test one or two of each lot of bars to destruction, in order to find out the quality of the rest, than it is to burn up a Chinese village to get roast pig.

If the user would analyze, not 1 but 20 samples of the steel that meets a particular want, and then base his order on an analysis that should come within the highest and lowest limits of the samples, he would get substantially the same metal every time. The problem is a more difficult one for the steel maker, since he must analyze the many materials that go into his product; but if he imposes the same restrictions on the makers of these materials—in short, if from the ore and limestone and coal, up to the finished bar, each user buys by analysis, and pays in proportion to uniformity, the production of steel of the most multiform grades and qualities, each homogeneous and uniform to any extent of production, becomes a possible, if not a comparatively easy, matter.

What are Sir William Fairbairn, and Mr. Barlow, and Mr. Kirkaldy, and the other great experimenters in the physical properties of steel—in its adaptation to certain specific uses—what are they doing to relieve the engineering world from these uncertainties? They are simply discovering the vast number of qualities which

steel may be made to possess, without giving more than a clue to the method by which these qualities may be predetermined and reproduced. They are going to a vast expense of time and material to inform us, not that a certain combination of metals, but that a bar of steel, has such resistance and elasticity. This sort of experimenting has much the same value as the steam engine tests of a late chief engineer in the navy, of whom it is said, that in a coal consumption test he would calculate the ashes to ten places of decimals, and guess at the coal put into the furnaces.

Moreover, Sir William Fairbairn may be doing injustice to other steel makers, to Brown, Campbell, and Bessemer—bars of whose steel he has also similarly tested, and found not quite so suitable for certain purposes as the Barrow bars are. But he neglects to make it clear that the disparaged bars may be better than these particular Barrow bars for other purposes. He makes the mistake which we should suppose Sir William, of all men, would not make, of being absurdly general and random in one element of his conclusions, while he is fractionally accurate in others—of cramming the whole matter of chemical ingredients into the terms "hard" and "soft."

The first and easiest step in the desired direction is to find out what *X* is. It is not necessarily a bar of steel made by Turton & Sons, which one tool maker will swear by, and another will swear at; nor is it necessarily a boiler plate steel which Park Bros. made once, and Firth got at twice, and Singer, Nimick & Co. hit two or three times. It is a steel which Turton, and Firth, and Park, and Singer can, either of them, make by the 10,000 tons, if you will only tell them what it is made of, as well as what its physical qualities are. In the various uses to which engineers have applied steel, there are a vast number of specimens which have long fulfilled all the requirements. When more steel of the same sort is wanted, the usual method is either to apply to the same maker, who kept no complete record, and does not know what is wanted; or to get bids based on a stereotyped and very inadequate physical test, for instance, that the bar must stand such and such a blow from a drop. The lot of steel is made, and is, as well it may be, very heterogeneous in physical character, although it may be in accordance with the one test. The result is that, under wear, some of it fails, or, under load, an excessive margin of safety must be allowed. The obviously rational way to reproduce a lot of steel which is proved suitable for any purpose, is to analyze many samples of it—at least for carbon, manganese, silicon, phosphorus, and any element which exceeds $\frac{1}{10}$ of 1 per cent., and thus to give the steel maker a recipe for making it.

It may be suggested that this chemical synthesis of steel will be ruinously costly. For certain exact purposes, such as the members of a long-span bridge; or for certain fine purposes, such as gun-barrels, the cost of analysis, or any loss in applying to other uses the lots of steel that were not up to the mark, would be very small, compared with the extraordinary margin of strength that must be given to an uncertain metal, and compared with the cost of occasional failures under final test. And this cost, whatever it is, the user—that is to say, the public, should and must bear.

But steel makers will find that working by analysis is not so very formidable, after all. The color test of carbon is already applied to all charges of all Bessemer and open hearth makers, and it is one of the most important. There is another view of the case: After a certain experience in comparing mechanical tests, which are comparatively easily made, with the more costly determinations of manganese, phosphorus etc., the expert will not need to analyze every charge. He will learn to read manganese, approximately, in an elastic limit test, just as the expert blacksmith can now read carbon quite accurately by the water hardening test. Herein will lie one of the values of the combined mechanical and chemical tests—that they will supplement and prove each other.

When the proper amounts of carbon, manganese, silicon, etc., for certain uses are known, it will not be impossible to approximate to them, in the Bessemer process, to a very helpful degree, and in the open hearth and crucible process, to a reasonably accurate degree. Of course, the character of the ingredients must be much more definitely known than at present, and numerous batches of nominally the same ingredient, such as pig iron, blooms, or puddle balls, must be mixed, so as to largely dilute any high degree of impurity which any one batch may contain.

The thing first in order is, of course, to ascertain the mechanical properties of all

grades of steel—not merely the individual resistances to destructive strains, which are but the stones that compose the mosaic, but the resistance within the elastic limit, which is the finished picture. To this end experiments like those of Sir William Fairbairn are indispensable, but to these must be added analyses of every grade of steel that can be produced, or the character of the metal is but half known.

In the present state of constructive and metallurgical art, it thus seems not only vitally important, but highly feasible, to increase in a large degree the uniformity of all grades of steel, and to make grades adapted to all special uses, instead of following the hit-or-miss and large-margin system, or want of system, that now obtains. Of course the change must come slowly, and its early stages will be attended with difficulty and expense; but there can be no question as to its ultimate success and its immense advantage in constructive and manufacturing engineering and art.

What probable expense of experimenting is to be considered when it will increase, possibly double, the resistance of metals to specific stresses, and decrease the present enormous margin of safety? It seems unaccountable that Government commissioners have so long neglected the chemical half of the problem—have so long neglected to complete the circuit, so that the metal will tell us its own story.

STRENGTH OF BOILER SHELLS.*

From the "Nautical Magazine" and "Engineering."

1. The Board of Trade, while allowing their surveyors to choose their own forms of calculation, have all along recognized as the fundamental principle of their practice, the following opinion, expressed by Sir William Fairbairn, in 1854, viz.: "Steam boilers of every description should be constructed of sufficient strength to resist 8 times the working pressure, and no boiler should be worked, under any circumstances whatever, unless provided with at least 2—I prefer 3—sufficiently capacious safety valves."

2. In 1868, each of the surveyors were called upon to send to the Board of Trade a report, giving in detail a statement of the rules they used in determining the working pressures to be allowed on the boilers that came under their survey, and their method of inspection. It appeared from these reports that although the arithmetical forms of calculation were not uniform, yet the results arrived at were, in every case, so nearly alike, and were also so near to the pressure required by the maxim laid down by Sir William Fairbairn, that the Board did not, in the case of any one of the reports, interfere with the method of calculation the surveyor had adopted.

3. The most of the surveyors gave as their practice, a rule that had been long well known amongst engineers as "Galloway's rule," and as both manufacturers and surveyors seemed to have the same rule, there did not appear to be any occasion for upsetting a practice that was working so well. In some of these reports, however, a matter was introduced as affecting in an important degree the practical value of "Galloway's rule," viz., the actual proportions of riveted seams. It is stated that manufacturers were departing from certain proportions for which alone Galloway's rule was applicable. As this divergence has since led to considerable misunderstanding between manufacturers and the Board's surveyors, it may be interesting to explain what has been the nature of this difference. To understand that, it will be necessary to go to the origination of the rule.

4. The rule in question was formed by the late chief surveyor, Mr. Galloway, as an embodiment, in a practical form, of the practice of the Board's surveyors in carrying out the principle above quoted from Sir William Fairbairn, that the actual factor of safety in all steam boilers should not be less than 8. The following is the rationale of the construction of Galloway's rule.

5. In the absence of tests witnessed by an officer of the Board of Trade, the strength of iron is assumed to be 48,000 lbs. per sq. in. in plates and rivets; this includes the effect of friction at the joints, and supposes the holes to be drilled, the

* We are indebted to the "Nautical Magazine" for the above article, and for some additions to it, which were kindly forwarded to us in reply to our request for permission to reprint.

strain to be applied lengthways to the plate, and the rivets to be Lowmoor, or equal to that in quality. When the rivets are subjected to double shear, or where the strain is applied crossways to the plate, only 43,000 lbs. is allowed as the strength per square inch of the rivet, or of the plate respectively. The other details of strength standards will be given further on; the first of these statements is all that is necessary to explain Galloway's rule. In that rule the section of the shell is taken as the length of the boiler by the thickness of the plate; but practically, the length of section will be greater than the length of the boiler on account of the doubling of the plates at the circumferential seams. When the double riveting is zigzag, as it should always be in boiler shells, the section is increased about 7 per cent. by this extra material. To give effect to this, the 48,000 lbs. was increased about 7 per cent., or to 51,520 lbs., or 23 tons.

6. According to Fairbairn, the strength of properly proportioned double riveted joints is 70 per cent. of that of the solid plate, and as the shift of butts longitudinally in the shell plating should be at least one strake, the weakest section will be alternately a solid plate and a riveted seam, or

$$\frac{100 + 70}{2} = 85 \text{ per cent.}$$

as the average strength of the whole section as compared with the solid plate. To permit retaining the 70 per cent. as the description of the riveting instead of altering this percentage to 85, an equivalent reduction was made upon the factor of safety 8, by substituting for it a divisor, 6.5;

$$\frac{70 \times 8}{85} \text{ being nearly equal to } 6.5.$$

7. For single riveted seams the excess for laps is proportionately less, and the addition of strength by the shift of butts is proportionately more, and the resultant is approximately also the substitution of a divisor, 6.5, instead of the factor of safety, 8.

As

$$\frac{23 \times 2240 \times .70}{6.5} = 5550,$$

and

$$\frac{23 \times 2240 \times .56}{6.5} = 4440.$$

"Galloway's rule" assumed the following form for boilers of the best construction and workmanship, the dimensions being taken in inches:

$$\frac{5550 \times \text{twice the thickness}}{\text{diameter of the boiler.}} = \left\{\begin{array}{l}\text{Allowed pressure for}\\ \text{70 per cent. double}\\ \text{riveting.}\end{array}\right.$$

$$\frac{4440 \times \text{twice the thickness}}{\text{diameter of the boiler.}} = \left\{\begin{array}{l}\text{Allowed pressure for}\\ \text{56 per cent. single}\\ \text{riveting.}\end{array}\right.$$

8. In this form "Galloway's rule" became well known, but, unfortunately, those outside the Board of Trade, in many cases, soon lost sight of its fundamental principle, viz., the actual factor of safety to be 8, and of the standard of riveting to which alone it applied, viz., 70 per cent. in the double riveted joint, and 56 per cent. in the single riveted joints. As with the spread of compound engines higher pressures became general, and the thickness of shell plates was increased, the 70 per cent standard was not adhered to by manufacturers, and in some cases the strength of double riveted joints was actually less than 56 per cent, which was the standard for single riveting in the construction of "Galloway's rule."

9. Manufacturers, in these cases, although they had departed so far from the principle of the rule in their proportions, nevertheless continued to calculate the pressures by "Galloway's 70 per cent. rule," and, of course, the pressures they expected were not allowed by the Board of Trade.

10. "Galloway's rule" is altered in the following way to suit different strengths of double riveted seams, the joints being properly crossed:

Rule,

$$\frac{(515 \times (70 + \text{percentage}) \times \text{thickness of plate}}{6.5 \times \text{diameter of boiler}} = \text{pressure.}$$

Or nearly

$$\frac{70 + \text{percentage}) \times 80 \times \text{thickness}}{\text{diameter}} = \text{pressure.}$$

For single riveted seams, substitute 56 or 70 in the above.

The "percentage" to be used in the above is the least of the two valves found by formula in paragraph 19.

11. Mr. Galloway's rule was made for boilers of the best workmanship, and for plates much thinner than those now common in high-pressure boilers. The increase in thickness has not only caused a departure from the 70 per cent. standard, but it has in many other respects lessened the strength per square inch of section of the shells of boilers; the bending of a plate in the rolls, after the end holes are in, is more

injurious to a thick plate than it would be to a thinner one; thick plates have less tensile strength per square inch of section than thinner plates have.

12. Board of Trade surveyors have always been influenced by such considerations in fixing the pressures to be allowed on boilers. In applying to ordinary marine boilers the reductions which, according to even the most liberal interpretation of a surveyor's duty, are seen to be necessary to maintain in its integrity the maxim laid down by Sir W. Fairbairn, the pressures allowed fall, in many cases, far below the pressure resulting from the current misapplication of the popular form of Galloway's rule, and the disappointment to manufacturers, and their complaints, laid at the door of the Board of Trade, should be recognized as due to themselves only, and should be taken upon their own shoulders.

13. Two courses of action are open to manufacturers, either to combat the opinion of Sir William Fairbairn and have it expunged from the standard code of engineering practice, or, on the other hand, to adopt such improved methods of construction or stronger materials as will justify a higher pressure in accordance with that opinion.

14. The responsibility upon the Board of Trade is a very serious one, but, at the same time, their duty is very clear. So long as the above statement of opinion stands uncontroverted, the travelling public have a right to demand from the Board of Trade the condition of safety therein defined. I, as a surveyor, may or may not consider such a margin of safety as in every case necessary, but it would never do for every surveyor to set about experimenting with the lives of the public to discover whether he or Sir William Fairbairn were the better authority on this point. It is clearly understood that this factor of safety is a matter of settled policy, not one for the exercise of individual opinion. But what surveyors cannot do, and what even the Board of Trade ought not to do, it is still open to the great engineering lights of the day to do. They may alter public opinion, they may refute the statement on which the Board's policy rests, and they might even succeed in getting Sir William to retract his statement and to side with those who are opposed to it, and then there is no doubt that the Board of Trade would not consider it their duty to force upon the public a higher degree of safety than the public themselves cared to possess.

15. In this paper my object has been to explain and to justify the action of surveyors in fixing pressures. Galloway's rule, although at the bottom substantially correct, was, in reality, only an empirical formula, and it is, perhaps, to be regretted that the more detailed, although less practical method originally adopted was ever departed from. According to that system the bursting pressure was calculated from the dimensions of the boiler taken in detail, and that pressure divided by 8, gave the working pressure.

16. In applying this principle in the case of boiler shells, the Board's surveyors do not reckon the ends of a circular boiler as adding anything to the strength of the weakest section, and they take into account the actual percentage of strength left in the riveted seams, as found by paragraph 19, and they allow for the extra section afforded by the laps of the plates, or by butt straps, and by the crossing of the plates; they make the proper deductions for openings in the shell, and they calculate the pressure to be allowed for the dimensions of the weakest section, not the mean of two opposite sections, but the weakest section at one side of the shell only.

17. In the absence of tests witnessed by an officer of the Board of Trade, the following are assumed to be the strengths of the materials:

	lb. per sq. in.
Plates, lengthways, drilled.....	48,000
" crossways "	43,000
" lengthways, punched.....	40,000
" crossways "	36,000
Rivets, Lowmoor, single shear.....	48,000
" " double "	43,000
" common, single "	40,000
" " double "	36,000

18. The strength of the whole of the weakest section is taken piece by piece, and the sum divided by the half diameter of the shell is the bursting pressure.

19. The strength of the longitudinal riveted seams in percentage of the solid plate is calculated by the least of the two following percentages:

Plates. $\left\{ \frac{(\text{Pitch—diameter of rivet}) \times 10 \times 10}{\text{pitch}} = \left\{ \begin{array}{l} \text{Percentage of plate at joint, as compared with the strength of the solid plate.} \end{array} \right. \right.$

If the holes are *punched*, substitute 8½ for one of the *tens*. If the strain is applied crossways to the plates, substitute *nine* for one of the *tens*. If the plates are bent after the end holes are in, substitute 9 for one of the *tens*. The last two of these substitutions will never be both required for properly constructed circular boilers.

Rivets.

$$\frac{\text{Area of rivet} \times \text{No. of rows of rivets} \times 10 \times 10}{\text{pitch} \times \text{thickness of plate.}} =$$

per centage of strength of rivets, as compared with the strength of the solid plate.

When the rivets are subjected to double shear, the *number of rivet sections to be sheared* is to be substituted for the *number of rows of rivets*, and the number *nine* is to be substituted for one of the *tens* in the above.

When the rivets are only of common rivet iron, instead of being of Lowmoor, or similar iron, $8\frac{1}{2}$ is to be substituted for one of the *tens* in the above.

20. The weakest section may run through seams all along if the shift of butt be not sufficient, or it may run alternately through a seam and a solid plate; the latter is the line it usually takes. The strength of the shell is then nearly a mean between the strength of the seam and the strength of the solid plate, or with a 70 per cent. seam we get

$$\frac{100 + 70}{2} = 85 \text{ per cent.},$$

and the extra for material in laps has to be added. The rule used for the minimum shift of butts is

$$\frac{110 - \text{percentage of riveting}}{\text{percentage of riveting}} = \text{length of shift of butts}$$

expressed as a portion of the whole breadth of the plate.

Example.—If the percentage of strength of the seam be 70, we have

$$\frac{110 - 70}{70} = \frac{40}{70} = .57 \text{ of the breadth of the plate.}$$

The addition of 10 to the 100 is intended as an equivalent for the metal in the circumferential laps, and to give the quotient, so that it can be applied from centre of seam to centre of seam, instead of between seams.

This shift of butts makes the strength of the intercepted circumferential seam at one of the seams equal to the deficiency between the strength of one of the longitudinal seams and a solid plate of the same breadth. In boilers plated after the pattern of brick bond, as is the general custom, only every alternate longitudinal seam has to be supplemented by the strength in the shift, and consequently the strength of both of the intercepted portions is taken into account. In common plating, therefore, only half of the shift given by the above rule is required, and the rule is meant for the system of plating advocated in next paragraph. Strictly, the percentage of riveting used in the denominator should be that percentage which is due to the rivets, not that due to the plates, but using the least of the two, as in the above, will err, if at all, on the safe side.

21. If manufacturers desire higher pressures, here is an inexpensive way to secure greater strength: economize the shift of butts; instead of always making the shift equal to half the length of the plate make it equal to $\frac{1}{3}$ or $\frac{1}{4}$ of the length. If the length of the plate, from centre of seam to centre of seam, be equal to n times the length of shift of butts, and if the percentage of the strength of the seam be given, we have

$$\frac{100\,(n-1) + \text{percentage}}{n} = \left\{\begin{array}{l}\text{percentage of strength of}\\ \text{shell as compared with}\\ \text{solid plate,}\end{array}\right.$$

besides the strength due to the extra material in the circumferential laps.

22. This system has never been adopted in any boiler submitted for survey, although its value in making up the longitudinal strength of a ship's hull is a fact well known to engineers. The boiler ends, never being calculated directly, may, in this way, be indirectly made available in adding to the strength elements of the boiler shell by observing that there is always a good shift left between the seams in the end and those in the extreme plates of the barrel of the shell.

23. In this journal for May and for June of last year there appeared articles on the strength of riveted seams, both by Board of Trade surveyors. The present article, also by a Board of Trade surveyor, agrees throughout with those articles, except in one item, that here the strength of boiler plate is taken as 48,000 instead of 47,000 lbs. The values given in the present paper are in extension of the principle followed out in Mr. Wymer's paper in the May number, which applied only to equal values for the strength of rivet and of plate.

24. If the plates of the shell are not of excessive width, say total width not more than 40 times their thickness, the above principles would be applicable and with riveting, whose proportionate strength was even only 60 per cent., the strength of the shell could be made nearly equal to solid plate. Example:—

$$\frac{110 - 60}{60} = .83.$$

The circumferential shift of butts would be .83 of the breadth of the plate, say plates 36 in. wide, the shift would be $36 \times .83 = 30$ in.

25. If the longitudinal shifts be made three strakes apart, that is on the fourth strake, the length of the plate, centre of

seam to centre of seam, will be $4 \times 30 = 10$ ft. The strength of shell would be

$$\frac{100\,(n-1)\,+\,\text{percentage}}{n} = \frac{360}{4} = 90 \text{ per cent.}$$

If the material in circumferential laps amounts to 7 per cent. extra, that is about $2\frac{1}{2}$ in. at each lap, the total strength of shell will be

$$90 \times 1.07 = 96 \text{ per cent. of the solid plate;}$$

or, 107 might be used instead of 100 in the preceding formula; this would drop the 7 per cent. on the seam and allow for thinning the corners.

And if the strength of the plate be 48,000 lbs. per square inch, for the effect of punching has been already accounted for in the low percentage taken for the riveting, we get

$$48{,}000 \times .96 = 46{,}080 \text{ lbs. per sq. in. as the strength of the shell.}$$

The eight part of this is the working strain,

$$\frac{46{,}080}{8} = 5760,$$

or a little more than the working strain allowed per square inch according to the popular form of Galloway's rule for 70 per cent. joints and drilled holes. With the butts arranged as above, and the plates of sufficient length, if the strength of the seam were even as low as 45 per cent. the pressure to be allowed would still work out to be as high as that due to 5,500 lbs. per square inch of gross section. It is evident, therefore, that if a pressure be given less than that due to Galloway's supposed rule, manufacturers have only themselves to blame. The additional strength pointed out would be obtained at absolutely no extra cost.

26. The thick plates of marine boilers should always be double riveted, even although the required pressure may be arithmetically due to an arrangement of single-riveted seams.

27. The principle of the calculation herein set forth takes advantage of every known element of strength in the shell, and assigns to it its full value. It is not strictly accurate, because it is impossible to determine the actual conditions of strain in any composite structure; but the system of averages, or the hypothesis of equal distribution of load, is the basis of all engineering estimates of strength. For the high-pressure boilers to which this paper is directed, the plates are generally narrower in comparison to their thickness than the thinner plates of single-riveted smaller boilers. In Fairbairn's writings on strength of boilers he gives as the strength of a single-riveted seam 56 per cent. of that of the solid plate. These plates have generally a breadth about equal to 100 times their thickness; but Fairbairn states that such boilers, by reason of brick bond crossing of the joints, have their strength increased 20 per cent. In accordance with that, he gives the strength of single-riveted boiler shells as 20 per cent. in excess of the strength of the riveted joint, and he forms the constants for his rules not upon 56 per cent. but upon

$$56 \times 1.20 = 67.2,$$

or 67 per cent. of the strength of the joint.

If we increase the 70 per cent. due to double-riveted joints *per se* in the same proportion, we would have

$$70 \times 1.20 = 84,$$

or nearly equal to

$$\frac{100 + 70}{2} = 85 \text{ per cent.,}$$

as used in this paper. I am aware that this mode of increase by percentage is not engineeringly correct, but its argument is better understood by some readers than is the system of means I have worked upon.

28. To some minds it may appear that a considerable reduction ought to be made on the mean of the strengths of the elements of the weakest section. To all engineering structures the same objection applies; the gross load is divided over the gross section, and the "breaking load" is that which would produce destruction, on the hypothesis that every element of strength will be effective up to its calculated individual strength. To a greater or less extent such a condition never exists in practice, and if this paper had been directed exclusively to the strength of brick bond plating, a small reduction, certainly not amounting to sacrificing the strength due to the extra material in the circumferential laps, might have been proposed as an equivalent; but as my object has been the better disposition of the plates, so that the amount of riveted joint in the weakest section is always only a very small percentage of the total section, the proper reduction would be too small to have any importance.

MODERN LOCOMOTIVES.*

From "Iron."

The author commenced by stating that in the present day, with a view to lessen the capital expenditure on railways, engineers have been compelled to follow more closely the contour of the country both as regarded the vertical profile and the general direction of valleys and hills. The consequence had been severe gradients, often concurrent with curves of small radius. This fact, taken in conjunction with the circumstance that in the colonies and in less developed districts, high speeds and frequent communication were not necessary, had led to the employment of heavy engines for the purpose of gaining great tractive power, since load rather than speed was the desideratum. A like state of things existed in most parts of the Continent of Europe, where heavy and slow trains, both of passengers and goods, were the rule; thus permitting the service to be carried on at a much lower rate per ton per mile than the rapid traffic of Great Britain rendered possible. Of late years the passenger traffic had so increased in the United Kingdom that even express trains were now worked, for the most part, with coupled engines, the additional points of contact with the rails being imperative in order to prevent slipping, and to afford greater facility in starting. Increase in the size of engines had everywhere been found to be a necessity, and while the outside frames of inside cylinder engines had been generally abandoned, the inside cylinder arrangement had been almost universally adopted, notwithstanding the disadvantage it presented of a cranked driving-axle.

The details of construction of different types of engines and their adaptation to the work required were then described. Attention was first directed to the Great Northern Railway express engine, in which outside cylinders had been resumed, perhaps as a necessary consequence of the adoption of a bogie frame with four wheels, instead of a pair of leading wheels, to insure greater freedom in passing round curves at high speeds. The cylinders were 18 inches in diameter, with a length of stroke of 28 inches —a size, it is believed, never before attempted for passenger engines in this country. The small ends of the connecting rods were furnished with solid bushes of gun-metal, and had run more than 50,000 miles without renewal. The inner and the outer fire-boxes were connected together by stays screwed into each of the plates without the intervention of iron girder bars. By this arrangement, which had been in use for some time in Belgium, the large amount of deposit usually existing upon girder-boxes was prevented, the facility for cleansing was much greater, and the liability of the tube-holes in the copper plate to become oval had been got rid of. The heating surface in this engine was—in the tubes, 1,043 sq. ft. and in the fire-box 122 sq. ft. The fire-grate had an area of 17.6 sq. ft. When the engine was in working order, the weights upon the driving and hind wheels and upon the bogie were 15, 8, and 15 tons respectively. The distance from the centre of the hind wheels to the centre of the bogie pin was 19 ft. 5 inches. This engine was capable of drawing a weight of 356 tons on a level at a speed of 45 miles an hour, with a working pressure of 140 lbs. to the sq. in. The consumption of coal, with trains averaging 16 carriages of 13 tons weight each, had been 27 lbs. per mile, including getting up steam and piloting. The cost of maintaining and renewing passenger engines on the Great Northern Railway was estimated to amount to 2½d. per mile.

The next example selected was the London and North Western Railway fast passenger engine. In this case the cylinders were inside, between the frames—in the smoke-box, in fact,—and had a diameter of 17 inches, with a length of stroke of 24 inches. The boiler was fed by two Giffard injectors, placed vertically behind the fire-box. The admission of water to the injector was regulated by a screw with a wheel handle. The water ascended, and passed through a clack box (which could be closed at pleasure) into the boiler along an internal pipe, carried forward two-thirds of the length of the barrel of the boiler; all external pipes running forward outside the boiler were thus done away with, and greater simplicity and freedom from accidents were secured. The heating surface in this engine was

* A paper read before the Institution of Civil Engineers (London) by John Robinson, C. E.

1,013 sq. ft. in the tubes, and 89 sq. ft. in the fire-box. The area of the fire-grate was 15 sq. ft. The distribution of the weight on the wheels, when the engine was in working order, was 9 tons 9 cwt., 11 tons and 8 tons 15 cwt. on the leading, driving, and trailing axles respectively. The total wheel base was 15 ft. 8 in. This engine would draw a load of 293 tons on a level at a speed of 45 miles an hour, with a working pressure of 120 lbs. to the sq. in. The consumption of coal per mile was 20.3 lbs. with trains averaging 10 carriages; and the cost of repairs, over a period of six years and a half, had been 0.52d. per mile run.

The six-wheeled coupled goods engine, made for the Great Southern and Western Railway of Scotland, and consequently suited for a gauge of 5 ft. 3 in., was next described. In this case the cylinders were 17 in. in diameter, with a length of stroke of 24 in. The tires of the wheels and axles were of cast steel. The coupling rod ends were furnished with cast iron bushes, lined with white metal. The small ends of the connecting rods had wrought iron steps, case-hardened. Sand-boxes were fixed in the smoke-box; and a steam brake was applied. The heating surface in the tubes was 846, and in the fire-box 93 sq. ft. The fire grate had an area of 17½ sq. ft. The weights upon the leading, driving, and trailing wheels were 10 tons 17 cwt., 11 tons 7 cwt., and 8 tons 15 cwt. respectively. The total wheel base was 15 ft. 6 in. This engine would draw a load of 607 tons on a level, at a speed of 25 miles an hour, with a working pressure of 140 lbs. to the sq. in. The average consumption of coal was 35 lbs. per mile with a load of 55 wagons. The cost of repairs had been 0.63d. per mile.

The next engine referred to had been specially designed for the heavy goods traffic on the Bombay, Baroda, and Central India Railway, where the gauge (5 ft. 6 in.) had afforded great facilities for the construction of a powerful machine on a reasonable length of wheel base. The cylinders were 18 in. in diameter, with a stroke of 24 in. The escape of smoke when the engine was standing still was prevented by the application of Mr. D. K. Clark's apparatus for the introduction of air above the surface of the fire. There were 1,278 sq. ft. of heating surface in the tubes, and 99 sq. ft. in the fire-box. The area of the fire-grate was 25½ sq. ft. This engine would draw a load of 694 tons on a level, at a speed of 25 miles an hour, with a working pressure of 140 lbs. The consumption of coal was 59¼ lbs. per mile for an average load of 490 tons. The cost of repairs had been 3-22d. per mile. A peculiar feature of this engine was the position of the hind axle under the fire-box, permitted by the shallowness of the end of the latter. This arrangement answered the double purpose of allowing a comparatively short-wheel base and an equable distribution of the weight of the engine upon the wheels, 11 tons, 11 tons 16 cwt., and 11 tons 16 cwt. being carried on the leading, the trailing, and the driving wheels respectively.

The locomotive next described was of the class usually called "tank engine," and was constructed for the conveyance of mineral or heavy goods traffic over a portion of the Furness railways, having gradients of 1 in 100, 1 in 80, etc., for eleven miles. This engine was designed to obtain as much power as was possible on six wheels. The frames had been put inside the wheels to allow convenient access to the motive parts; the cylinders being placed inside to secure great structural stability. The cylinders were 18 in. diameter, with a stroke of 24 in. Tanks, to contain 1,000 gallons of water, were arranged along each side of the smoke-box, the boiler, and the fire-box, above the level of the frame, so as to distribute equal weights upon the wheels, which, when the engine was in working order and the tanks were full, were 13 tons 6 cwt., 14 tons 11 cwt., and 13 tons 8 cwt. on the leading, driving, and trailing wheels respectively. The total wheel base was 15 ft., the heating furnace in the tubes was 1,048, and in the fire box 96 sq. ft.; the area of the fire-grate was 15 sq. ft. This engine would draw a weight of 872 tons on a level at a speed of 20 miles an hour, and a weight of 367 tons up the incline of 1 in 80 at a speed of 11¾ miles an hour, with a working pressure of 145 lbs. to the sq. in. The consumption of fuel with this latter load had been 40.16 lbs. per mile.

For engines with rigid frames, a simple and convenient arrangement had recently been applied in the shape of a sliding top to the leading, and sometimes to the trail-axle-boxes. This cap had a double incline in the transverse direction of the engine. The axle-box had also similar correspond-

ing inclines, so that when passing round a curve the leading wheels were free to move sideways without at once carrying the engine with them. This plan had been largely adopted on the Midland Railway.

Details were then furnished of the Fairlie system of locomotives, designed with the object of giving extreme freedom of movement to the engine and wheels, while securing sufficient stability to the boilers and their adjuncts. It had likewise been sought to utilize the whole weight of the fuel and water for the purposes of tractive adhesion. In conclusion, the author alluded to the great advantages which had accrued to the users of locomotive engines by the adoption of steel instead of iron for many parts, especially for tires and axles, whether the latter were cranked or straight.

SAFETY OF NAVIGATION.

From "The Nautical Gazette."

The American Association for the Advancement of Science enjoyed a most interesting session at Portland, Me. From one of the papers presented we make the following extracts:

Paper No. 37 of the catalogue was "The Coefficient of Safety in Navigation; an attempt to ascertain within what limits a ship can be located at sea by astronomical observation." The problem to be solved is to obtain average number of miles error which may be fairly charged upon an observation at sea under ordinary circumstances. The coefficient of safety is the quantity by which this number must be multiplied to secure absolute safety. I define it to be the ratio between the average error and the range of error. To show that this is not idle inquiry, the ratio of the increase of the number of vessels was compared with that of the number of wrecks, and the results certainly go far to confirm the practical value of the theory. The problem of wrecks was discussed under four heads:

1. Wrecks produced by causes purely beyond human control.

2. Wrecks caused directly or indirectly by over insurance.

3. Wrecks caused by deviation of the compass.

4. Wrecks caused by errors of observation at sea.

Under the first head the result was reached that about 70 per cent. of wrecks arise from preventable causes. Under the second head the result is found that more than three times as many insured as uninsured vessels are wrecked. Under the third division an abstract of the discussion of the problem of variation of the compass, both in wooden and iron ships, is given

Under the fourth division the two essentially different methods of finding the longitude at sea, viz.: the method by lunar distances and by chronometers, are explained and discussed, to ascertain which is the most accurate. From several hundred observations of each class the following tabular results were obtained:

Place and Circumstances of Observation.	Average error.	Range of error.	Coefficient.
	Miles.	Miles.	
Greenwich, Edinburgh, observations at each station, comparison of final results with truth.....	0.6	2 1	3 5
Washington, Greenwich, same as above.....	0.6	1.6	2.7
	0.6	1.8	3.1
Hudson, Greenwich, observations at each station, comparison with final mean	1.5	4.3	2 9
Brussels, Greenwich, same as above.	1.2	4 4	3.7
Places in Turkey by Struve, same as above.....	1.7	6.9	4 2
	1 4	4 8	3.6
Camp Riley, tabular places of moon.	3.5	13.8	3 9
Willet's Point, American ephemeris.	2.3	10.8	4.7
Willet's Point, British ephemeris ..	3.5	13.8	4.0
	3.1	12.8	4 2
Willet's Point lunars	10.2	24.2	2.4
Fisher's observations at sea	.....	25 0	....

The error of chronometers is then discussed in a similar manner, after a discussion of the various sources of error:

1. The rates of the best chronometers of 14 makers, left for trial at Greenwich Observatory, between 1842 and 1871, are discussed with the following results, calling minutes of arc miles:

Greatest change of daily rate in about six months:

	Miles
1842-53... 33)	(16.5
1853-62...38 ~ .....equal at end of 20 days. ~	19.0
1863-71....25)	(15.5

Greatest change of daily rate between one week and next:

1842-53....19)	(95
1853-62....19 ~ .....equal at end of 20 days. ~	95
1863-71....13)	(65

In order to show the great influence of temperature on rates, a discussion similar to the above is made of the finest and poorest chronometers left for trial between 1867 and 1871, selecting the four weeks of ordinary temperature immediately preceding four weeks of high temperature. The results are:

	Miles.
From mean of best chronometer at end of 20 days' error	29.0
From mean of poorest chronometer at end of 20 days' error	17.6

But the poorest chronometers are good compared with sea-going ones.

Combining the results, we find that the navigator must expect for his chronometer at the end of twenty days about an error of 3.6 miles, he must be on the lookout for an error at 11.5 miles, and he need not be surprised at an error of 21 miles, all on the supposition that he has only an average chronometer.

Attention is called to the great error arising from using an average rate for a whole voyage instead of rates for various temperatures.

The paper closes with a discussion of sextant observations on shore and at sea, from observations available between 1793 and 1871, arriving at the conclusion that under the most favorable circumstances the errors of observation alone are likely to exceed 2 miles, while ordinarily they are much larger. These errors are independent from chronometer errors, and must be added to them.

From a discussion of the results of 37 cases of runs for longitude of sea stations, mostly by British exploring expeditions, the following final results are found:

	Miles.
Mean error at end 11 days	4.4
Range of error	15.1
Average error of longitude	5.0
Greatest range between results	31.6

It is therefore safe to assert that a navigator who assumes that he can get the place of his ship certainly within 5 miles, or probably within 15 miles, exhibits an over-confidence which may lead him to ruin.

CALORIMETER IN LOCOMOTIVE ENGINE BOILERS.

From "The Engineer."

In a recent impression, when considering some of the peculiarities of the locomotives exhibited at Vienna and used on the Continent, we called attention to the enormous length of fire-tube adopted on many French, German, and Austrian railways, and we stated that these long tubes were rendered necessary because of the small area which they presented for the passage of the products of combustion as compared with the grate surface. The question thus raised is one of peculiar interest because tube surface is very expensive to construct and maintain, and we have reason to believe that most locomotive superintendents would willingly reduce it below existing limits if they deemed such a reduction consistent with economy of fuel. We shall not pretend to dogmatize on a question the true solution of which can only be reached by experiment, but we venture to think that time will not be wasted if we consider the problem even on a theoretical basis, so long as there is nothing in the theory absolutely inconsistent with practice.

It has long been known that the calorimeter—in other words, the gross aggregate area of escape through the flues of a boiler—exerts a very important influence on the quantity of fuel required to generate a given weight of steam. Very elaborate experiments have been carried out in this country and in the United States in order to arrive, if possible, at some law or rule on which to base the proportions which the calorimeter of a boiler should bear to the grate surface, but the attempt has not succeeded. All that is known certainly is that there is better area of calorimeter than any other for each particular boiler, for each particular duty exacted from that boiler, and for each particular coal used. Therefore no general law can be laid down. If, however, the coal and the duty are known, then it is possible

to decide what is the best calorimeter. Now, on most railways the work to be done by locomotives of a given class varies only within moderate limits, and the coal used is of very uniform quality. It appears, therefore, to be quite possible to decide by experiment what is the best calorimeter for each type of engine, and we have no doubt, as in a very large number of cases the calorimeter is not just what it ought to be, that, therefore, simple experiments would give information which could not fail to prove useful, and result in a saving of fuel. There are two points to be considered in dealing with this question. The first is, that if the calorimeter is made small, the velocity of the escaping products of combustion through the tube must be augmented. The second is, that if the calorimeter is made too great the gases are not retained sufficiently long in the fire-box, and much of its surface is rendered useless, principally because it is never filled by the flame, and the hinder surface, especially that nearest the fire-door, is reduced in efficiency. Besides this, the tubes will not be completely filled with hot gas, and a great deal of their surface will practically be wasted. In theory, the more slowly the heated gas can be made to traverse the tubes the better, but in practice it is found to be difficult to induce the gases to pass slowly and equally through all the tubes at different levels where so many are used, and in any case there is a strong tendency to deposit soot within them, which is eminently objectionable. It would appear, therefore, that upon the whole, regarding the problem from a strictly theoretical point of view, it is the best plan to use in locomotives very long tubes of moderate diameter—say two inches—and not to have more of them than will suffice to give a very small calorimeter. This is the principle generally adopted by Continental engineers. It is true that they are influenced in adopting this system by other considerations than those of economy of fuel, such, for instance, as the difficulty of getting more calorimeter if they wanted it; but the fact still remains, that the Continental system of constructing locomotive boilers supplies us with a distinct type possessing many advantages, whether that type has been forced upon its designers or been willingly, as we believe, adopted; and it will be found that within tolerably close limits, engineers, both here and abroad, have adopted similar proportions of tube to grate surface, the calorimeter also bearing such a relation to the tube length that the time occupied by the heated gas in escaping to the chimney will be nearly the same, although the velocity of the gas in the foreign is much greater than in the native or indigenous locomotive. For example: the great Semmering engine, which we illustrated in our last impression, has a grate surface of a little over 23 ft., and a calorimeter through the body of the tubes and neglecting ferrules, of about 553.5 sq. in., or in round numbers the calorimeter is one-sixth of the grate used. We may compare these figures with those supplied by a very usual English type of goods engine, with 207 tubes 2 in. in diameter, and 16 sq. ft. of grate, the tubes being about 11 ft. 6 in. long, as against 15 ft. 7½ in. in the Semmering engine. The calorimeter in this case is abouth one-fourth of the grate surface, or one-third greater than in the Semmering engine; but the tubes in the latter are not quite one-half longer than in the English engine. A comparison, however, of a number of Continental engines having long tubes with a number of English engines having tubes of about the normal length, goes to show that, as we have stated, the velocity of the gas in the Continental engines is about as much greater than it is in our engines in the same proportion that the tubes are longer. From this it results that less soot should be deposited in the smaller tubes, the tubes are better filled with gas, and the conditions of heat surrender are probably better. But on the other hand, the first cost of the boiler, and its weight, and expense of maintenance, are much increased. It is not easy, nevertheless, to say exactly at what point further augmentation of tube length ceases to pay; and it is possible that Continental engineers err in making tubes too long, while in this country we err in making them too short. A long tube requires more draught and causes more back pressure than a short one, other things being equal. But a boiler with short tubes, on the other hand, may waste so much heat, because of the escape of the gas uncooled, that a sharp draught may be essential to keep up steam, and thus all the evils of both too long and too short a tube may be met with in one and the same engine.

If we suppose the soot difficulty to be disposed of, it admits, in the same way, we think, of being proved that, provided a very

accurate distribution of the gas is effected, the nominal calorimeter of a boiler may be greatly increased, while the tubes are shortened, with much advantage. Now, a good deal depends on the fact that it is possible to retain the products of combustion for as long a time as we please in the furnace, and to make the rate of combustion what we like, within limits, without regard to the diameter or length of tube. If, then, while retaining a given current of air through the bars, we reduce the velocity through the tubes, we may reduce the tube length nearly in the same proportion. Thus, let the velocity of escape in one boiler with 2 in. tubes 12 ft. long, be 40 ft. per sec., then, by constructing another boiler with twice as many tubes half the length, the velocity would be reduced one half; but the economic efficiency of the boiler may be just as great, and there is no doubt that it would be as great, because portable engines with short wide tubes and an enormous nominal calorimeter excel most locomotives in economy of fuel, as has been proved time and again by the Royal Agricultural Society's trials. The great difficulty standing in the way of using short tubes and many of them, of good size, lies in the increase which would be required in the diameter of the boiler, and in the difficulty of making the gases distribute themselves equally. There is reason to think, however, that in many cases, and especially for working inclines, boilers with large barrels, say as much as 5 ft. in diameter, might be employed with advantage, the large nominal calorimeter which would be secured by a multitude of tubes, being reduced to a comparatively small true calorimeter by the use of ferrules at the smoke-box end, such as those employed by makers of racing portables. Be this as it may, we venture to think that any locomotive superintendent who has engines daily doing much the same work, may with much advantage carry out a simple experiment, by trying for a month at a time the effect produced in the consumption of fuel by the use of ferrules of varying thicknesses in the smoke-box. We are not aware that anything like a good set of experiments of the kind has been instituted in this country since coal came to be used as fuel on railways; and this is remarkable, because the cost of the experiment would be little or nothing, and the information to be obtained by it could not fail to prove valuable.

APPLIED ELECTRICITY.

A recent publication* reminds us that the application of electricity to its several practical purposes has risen to the rank of a distinct branch of engineering. A special training, as decided in character as that for a hydraulic or consulting steam engineer, is required in him who aspires to the position of an expert in electrical applications.

Electrical science now presents its own system of measures, together with both theoretical and empirical formulas for convenient use.

Our school text-books give no hints of such a branch of applied science. Popular scientific treatises on electricity bear about the same relation to the books for the electrician that descriptions of scenery along our rivers bear to hydraulic engineering. They serve to blind the novice to the fact that there is an economic value having some relation to the attractive phenomena.

The condition of our instruction books in this regard is just now eminently unsatisfactory. The books designed for the worker in this new field are far more *scientific* than those prepared for the student.

It is not a matter for surprise that the electrician requires instruments of peculiar construction, designed for measurement in his particular branch of industry, nor that he needs a table-book, looking much like that prepared for the railway surveyor, for these are necessities of a natural growth.

The little work of Mr. Haskins is evidently designed for just such frequent use as are any of the engineers' Pocket-Table-Books. In consequence, however, of the paucity of information within reach of the young learner, the author judiciously gives a brief outline of applied electrical science. We quote the book so for as to include the description of the instruments employed.

"To enable the student to work understandingly in galvanometric measurements, it is necessary that he should comprehend

*The Galvanometer and its Uses. A manual for Electricians and Students by C. H. Haskins. New York: D Van Nostrand.

the laws upon which such measurements are based.

"These laws we will state, in as few and simple words as possible; and the student, if he masters them thoroughly, will be enabled to understand readily what follows.

"All conductors offer a certain degree of *resistance* to the passage of the electric current through their substance. This resistance varies with defferent materials. The following table illustrates the comparative resistances of the most common metals to the passage of the current, silver being taken as the standard. The measurements are taken at 32 deg. Fahr.

Silver, hard	100
Copper, hard	100
Gold, hard	128
Iron	594
Tin	809
Lead	1202
Brass	450
German Silver	1282
Platinum and Silver	1493
Mercury	5815

Jenkin.

The resistance of metals increases with their thermometric heat. For instance, iron wire increases about .35 per cent. for each degree Fahrenheit above 60 deg.

"The conductivity (which is the reverse of resistance) of soft iron wire, suitable for telegraph purposes, is about $\frac{1}{6}$ that of commercial copper wire.

"The conductivity of any wire increases as its weight per foot.

"The resistance of any iron wire, per mile, is found by dividing 360,000 by the square of its diameter. The quotient will be in ohms at 60° Fahrenheit. This is expressed thus $\frac{360,000}{d^2}$, d being the diameter of the wire. Or it may be measured, as hereafter explained.

"Knowing, then, the resistance, per mile, that a given wire offers, or should offer, to the passage of a current, we have a basis for comparison, and can readily ascertain its electrical condition, and, when defective, apply a remedy where and when required.

"To determine accurately the amount or degree of resistance, we must have some standard that will serve us as the inch does in the measurement of distance, or a grain in estimating weight. Several of these standards have been made.

"But two standards, however, are now in general use, and these two only shall we note here.

"The Ohm is the standard unit, adopted by the British Association, and in general use in this country. It is equal to the resistance of a prism of pure mercury of 1 square millimetre section and 1.0486 metres length, at 32 deg. F.

"The Siemens Unit is equal to the resistance of a prism of pure mercury of 1 square millimetre section, and 1 metre long, at 32 deg. F. The Siemens Unit is in general use on the European continent, and to a considerable degree in the United States.

"To convert Siemens into Ohms, multiply by the decimal .9536.

"To convert Ohms into Siemens, multiply by 1.0486.

"Having found our units of measurement, we will now consider the laws governing the flow of the current.*

"The power which a cell of battery possesses of causing the transfer of its current from one place to another, is its electromotive force. In other words, the electromotive force of a current is its power of overcoming resistance—its energy. To use a familiar comparison, electromotive force is to a current what pressure is to steam.

"The amount of current that is evolved in a given time by a cell of battery is termed its quantity. This amount may be increased or diminished by lessening or increasing the resistance in circuit both in the battery and external thereto.

"While chemical action is going on in a battery, the current is being constantly accumulated, or piled up, at the positive pole of the battery, with a vigor depending entirely upon the electromotive force of the battery.

"The old theory, that the current thus accumulated flowed along the line-wire to the ground at the distant end, and back to the other terminal of the battery through the ground, is now generally abandoned, and the theory of M. Gavarret accepted as correct.

"He teaches that the earth, being a common receptacle and reservoir of electricity —hence termed the 'common reservoir'— has no electrical tension.

"When the current in a battery accumulates at the positive pole of the battery, its tension is greater than that of the earth.

* In examples given in this work, the term "unit" is used as a "unit of measurement," and may be read either as an Ohm or Siemens unit. When absolute measurements are given, the word Ohm or Siemens is always given to distinguish the kind of unit meant.

Now connect a wire from each end of the battery to the ground. If these wires are short and thick, thus having practically no resistance, the current will flow from the positive pole of the battery through the wire to the earth with a degree of energy depending upon its excess of tension over that of the earth. This action will continue, the earth receiving and absorbing from the positive pole of the battery where the tension is greater, and giving to the negative pole where the tension is less, until the action of the battery ceases from exhaustion, and the tension of the battery and the earth are equal.

"The effort, then, of the current evolved by the battery, is to equalize the tension or pressure, and produce an electrical equilibrium. This same inequality of tension between the clouds and the earth, is the cause of lightning-storms.

"If, in the case above supposed, the wires connecting the battery with the earth, were so long, or so thin, as to interpose considerable resistance to the passage of the current, the flow would be less in amount, and the chemical action of the battery less rapid—the current being dammed, or choked back, by the resistance to its passage.

"The amount of current, then, that will flow to line, depends upon and is proportionate to the resistance of the circuit. Hence, Ohm's law, which is the foundation of all electrical measurements.

Ohm's law is stated thus:

C being the amount of current,
E the electromotive force, and
R the resistance in the circuit.

$$C = \frac{E}{R}$$

or, the current flowing to line, equals the electromotive force divided by the resistance.

"The amount of current generated by a cell of battery depends upon the size of its plates—the tension, upon the number of cells.

"Hence, a battery of 40 cells, while giving 40 times the electromotive force, or tension * of one cell, will furnish only the same amount or quantity of current. Each cup of battery has its own quantity, which is urged forward to the next cell, by virtue of its own electromotive force. The current from the cell at the positive pole of the battery, is pushed out to the line wire, the current from the next cell taking its place—the last cell being supplied, through the ground-wire, from the earth. But the current from each cell, when carried forward to its neighbor, parts with its energy or electromotive force; and the current from the first cell is pushed forward to line, and thence to the ground at the further end of the line, with all the electromotive force, or energy, of all the cells.

"The amount of current flowing to line, from a given battery, is regulated, as we have seen, by the resistance of the circuit—and in this must be included the internal resistance of each cell of the battery. But, with a given total resistance, the flow of current may be increased.

"1st. By increasing the size of the cells, and thus decreasing the total resistance in the circuit; and,

"2d. By adding more cells.

"If we consider only the internal resistance of the cells, the addition of more cells will not increase the current.

"Thus, if we have 1 cell of battery, with an internal resistance of 2 units, and an electromotive force of, say, 10, and the poles connected by a wire having practically no resistance, the proportion of current flowing to line will be 5.

$$\frac{E = 10}{R = 2} = 5.$$

Now take 5 cells,

$$\frac{E = 5 \times 10 = 50}{R = 5 \times 2 = 10} = 5.$$

"The product is still 5, because the divisor and dividend are both changed in the same ratio.

"But suppose the resistance of the line-wire to be 5 units, represented by r. Then with 1 cell we have,

$$\frac{E = 10}{R + r = 7} = 1.43,$$

and with 5 cells,

$$\frac{E = 50}{R + r = 15} = 3.33,$$

or nearly three times as much current as before.

"It will be seen, therefore, that the proper method for adapting a battery to any line, with any instruments, is to select a form of battery giving sufficient current to saturate the magnets of the relays to their maximum, and then add a sufficient

* Electromotive force may be defined as tension in a state of motion; and tension, as electromotive force in a state of rest

number of cells, to drive it with the necessary force to produce the desired effect.

"The sum of the resistances of all the instruments in a circuit, should, as nearly as practicable, balance the resistance of the line-wire. In no case should they exceed the wire resistance.

"'When the resistance of the coils of the electro-magnet is equal to the resistance of the rest of the circuit, *i. e.*, the conducting wire and battery, the magnetic force is a maximum.'—(Noad's Text Book.)

"'The application of this law to a telegraphic circuit would be to make the sum of the resistances of all the magnet-coils in circuit, equal to the resistance of the line and batteries; but as in practice the resistance of a telegraphic circuit varies, being considerably reduced by defective insulation, the total resistance of the instruments should be less than that of the line when in good condition, to attain the best results during unfavorable weather.'—(Pope's Modern Practice, page 152.)

"A safe, practical rule for determining the number of cups of main battery needed, is to call the resistance of the relays equal to the line-wire, and use one cup of Grove, or bichromate of potash (electropoion), or two cells of Calland or Hill battery to each 100 units resistance in the circuit.

"Thus, for example: suppose a circuit of 200 miles No. 9 wire.

This will measure 20 units to the mile, or	4000 units.
8 relays in circuit, 500 units each	4000 "
Total resistance	8000 "

"For Grove or bichromate, divide by 100, and we get 80 cups battery, 40 at each terminal of the wire. For sulphate copper battery, divide by 50, and we find that we need 160 cups of battery, 80 at each end.

"These figures are true only of single wires. When several wires are worked from one battery, the total amount of battery used is of course much less. The number of lines—of about equal resistance—that may be worked from the same battery, varies greatly with different batteries, depending upon the chemical energy of the battery, the quantity of current evolved by it, and its liability to polarization.

"Thus the bichromate batteries of 80 cups, that we determined upon for our 8,000 unit line, will furnish current enough for several lines of the same resistance. But as we add wires we lessen the external resistance, until, owing to the slight resistance, the action is so rapid that the battery polarizes and action ceases. Practically, not over six to eight lines can be worked from this battery.

"With Grove it is different. Lines may be added to a Grove battery, with perfect safety, up to forty or fifty.

"The sulphate copper batteries have too much internal resistance to allow the addition of many wires. Three lines are worked from sulphate copper batteries having jars 6 in. in diameter.

In all cases, the expenditure or consumption of material in a battery is in exact proportion to the work done; that is, to the current evolved. Therefore, the expenditure of battery material, with three lines to a battery, is three times that of one line to the same battery, and there is no economy in working several lines from one battery, except in room occupied.

"The disadvantage of working several lines from one battery is the interference of the circuits with each other in bad weather. Sometimes this interference is quite serious. A greater number of cells of battery than is absolutely needed to work the circuit promptly, is injurious, and in wet weather, it tends to make the line work badly. Indeed, the effect of an excess of battery is often as detrimental to a line in wet weather as bad insulation, or a conducting wire of too high resistance.

"To explain this, the reader will remember that the difference in resistance between the line-wire and the insulators, is the margin upon which the line is worked. If that margin is diminished by bad insulation, a portion of the current escapes to the ground. If the resistance of the line-wire is increased, the margin is again diminished, and a portion of the current escapes as before.

"Now, the higher the tension of the battery current, the more readily will it escape from the line, because the greater is its power to overcome resistance. The effect, then, upon a wet day, is the same upon the line whether the insulation is defective, or the battery too large.*

"Thus it will be seen that adding more battery to a heavy-working line, will often,

*If, however, the escape is not very serious, it is sometimes beneficial to add battery to sending end until you have so high a current that, in addition to the large amount escaping, enough will reach the further end to work the relay. In this case the receiver must not attempt to "break."

in wet weather, make it work worse than before. And it will also be noted, that relays of high resistance, as they add to the resistance of the line-wire, decrease the working margin between the line and insulator resistance, and thus increase the tendency of the current to escape.

"When the relays of a line, of say 200 miles, are proportioned to the line itself, that is, do not exceed the line-wire resistance, and the battery is adapted to the circuit by the rule above given, if the line is well insulated, it will work well, in very bad weather, when a similar line, equipped with high resistance relays, or an excess of battery, will scarcely work at all.*

"Many experiments have been made to determine the speed of transmission of the electric current or influence through a wire. The first measurement, made by Wheatstone in 1833, showing a speed of 288,000 miles per second, was taken as the speed of the current under all circumstances. Subsequent measurements, however, showed such variable results, that confidence in Wheatstone's figures was much shaken. The following table shows the rates of speed noted by various experimenters:

Date.	Length of Circuit.	Velocity per Second	Observer.	Remarks.
1833	⅝ mile	288,000	Wheatstone	Leyden Jar.
1849	880	18,709	Walker	Relay.
"	590	16,000	"	"
"	607	28,500	Mitchell	"
1850	⅛60 iron	60,000	Fizeau & Gounelle	Galvanometer needle.
"	130 copper	114,000	" "	" "
"	1045	15,000	Gould	Relay.
"	447	17,000	Walker	"
"	2·0	13,000	"	Chemical Telegraph.
1854	104 iron	115,000	Guilleman & Burnouf	Galvanometer need'e.

"The above table gives no data from which to make any calculation or deduce any law. It only serves to show how varied were the results obtained. To be of any benefit, the experimenters should have given the conductivity, per mile, of the wire used, the form of battery, and the number of cells used in each case. The English, French, and German experimenters use, also, miles of different lengths.

"Thus, for land lines, we were without any reliable data until 1869, when Prof. G. W. Hough, of Dudley Observatory, and Mr. C. S. Jones, of Albany, New York, undertook a series of experiments to determine the velocity of the current. Mr. Jones, manager of the Western Union office, by looping wires to Boston, Detroit, New York, and Buffalo, obtained circuits of sufficient length to test the question thoroughly.

"As Grove battery was used, and the line-wire was galvanized No. 9, we have some data from which to draw satisfactory conclusions.

"On the 27th of May, Messrs. Hough and Jones obtained the following results:

Velocity per Second.	No. Cells of Battery.	Length of Circuit.
10,200 miles.	70	400 miles.
20 000 "	160	400 "
29,450 "	295	400 "
18,200 "	295	1000 "

"Prof. Hough remarks, in relation to the above results:

"'An inspection of these results show at a glance, that the velocity increases with the number of battery elements employed; also, for the same battery it decreases with the length of the circuit.'

"From these figures we deduce these facts:

"*First.*—That with a given resistance, the speed increases with the increase of the electromotive force, *i. e.*, the power to overcome resistance and urge the current forward.

"*Second.*—That with a given battery, the speed of the current varies as the re-

* A line that is suffering from bad escape may be worked much better for through business in bad weather, by switching off the battery at the receiving end of the line, and receiving only by the sending office current. Because, if there are heavy escapes on the line, the sending operator does not break all the current from the battery at the receiving end of the line, thus leaving the receiving relay partially magnetized constantly, and consequently less sensitive to the small portion of current from the sender that reaches the receiving station. Whereas, if the only current on the wire is that of the sender, the portion of his current that does reach the other end of the line comes clear and sharp.

sistance to be overcome in the circuit varies.

"And these facts explain why Wheatstone obtained a velocity of 288,000 miles per second, when Hough and Jones show less than 30,000 miles as their greatest velocity. Wheatstone used a Leyden jar, discharging a current therefrom of the higest tension, and having but a half mile of resistance of circuit, while the Albany experiments were made through long circuits, with battery-currents of comparatively very low tension.

"The effect of a moist or dry atmosphere on line measurements is too generally overlooked, especially on lines insulated with glass. As an insulator, glass is probably the best in dry weather, as it is certainly one of the worst when surrounded by a saturated atmosphere. Being an excellent radiator of heat, the glass insulator readily gives it out to the passing breeze, and speedily becomes cold, when the particles of moisture held in suspension in the air are deposited in a condensed form on the surface of the glass, thus forming a film of water, through which the current escapes.

"Again, even with the most perfect insulation, with a saturated atmosphere, a line will show considerable general escape. Frequently, a lower degree of insulation is shown just before a heavy rain than after it begins falling. And although the most careful experiments fail to show any escape through the atmosphere from one particle of moisture to another, yet this heavy escape is often noted, as above stated. When the rain begins falling, the moisture being condensed into drops, the continuity of the moisture seems destroyed, and the escape consequently checked.

"Whenever practicable, then, the percentage of saturation of the atmosphere, shown by a hygrometer, should be recorded, with the measurement, for future use, in comparing the condition of a line at different times.

"By attaching a second wire to a battery, a second path is provided for the current, and the resistance to its flow therefore lessened. If both wires are of exactly the same resistance, the effect is the same as if the first wire were taken off and replaced with one of just double the capacity, or weight per foot, or one of half its length of the same capacity.

"The joint resistance—that is, the resistance of all the wires attached to a battery—to the flow of its current, may be found as follows:

"If the resistance of the wires is equal, the sum of the resistances, divided by the square of their number, or the resistance of one wire, divided by the number of wires, will give the joint resistance.

"Thus, four wires of 100 ohms each:

1st method,

$$\frac{400}{16} = 25 \text{ ohms.}$$

2d method,

$$\frac{100}{4} = 25 \text{ ohms.}$$

"When the resistance of two wires is unequal, the resistance may be found by dividing their product by their sum.

"Suppose two wires of 200 and 300 ohms resistance,

$$\frac{200 \times 300}{200 + 300} = \frac{60.000}{500} = 120 \text{ ohms.}$$

"When more than two wires, find the joint resistance of the first two, as above; then take the result, considering it as a single wire, and proceed in the same manner.

"Suppose we have three wires, of 200, 300, and 280 ohms. The joint resistance of the first and second is, as we have seen, 120 ohms.

$$\frac{120 \times 280}{120 + 280} = \frac{33.600}{400} = 84 \text{ ohms,}$$

the joint resistance of the three wires.

"Or it may be obtained by the following formula:

"1st. Calling the three wires a, b, c,

$$\frac{abc}{ab + ac + bc}.$$

$$\frac{200 \times 300 \times 280}{200 \times 300 + 200 \times 280 + 300 \times 280} = 84 \text{ ohms.}$$

"2d. Divide one by the sum of the reciprocals* of their several resistances.

$$\frac{1}{\frac{1}{a} + \frac{1}{b} + \frac{1}{c}}$$

The reciprocal of 200 is.....	.005
" " 300 is	.00333 +
" " 280 is.....	.00357 +
	.01190

and,

$$\frac{1}{.01190} = 84 \text{ ohms.}$$

* The reciprocal of a number is the quotient of 1 divided by that number. Thus the reciprocal of 2, is $\frac{5}{10}$; of 20 is $\frac{5}{100}$.

"A magnetic needle will be deflected from the north by a current of electricity flowing in a conductor placed parallel to it. If the conductor is placed on top of the needle, and parallel, when the positive pole of the battery is attached to the south end of the conductor, and its negative end to the north end, the current will flow northward, and the north end of the needle will be deflected to the left. Reverse the current, and the north end will be deflected to the right. If the conductor is placed under the needle, the action will be in the reverse direction.

"The degree of deflection will be proportional to the strength of the current.

"If the conductor is carried over the face of the needle, and back underneath, the effect will be doubled. Wind the wire in several convolutions parallel to the needle, making a helix, with the needle in the centre, and you have the strongest form of galvanometer. The finer the wire, and the greater the number of convolutions, the more sensitive will the needle be to the current passing through the wire of the helix.

"By using fine German-silver or silver and platinum wire, the resistance of which is not affected by changes of temperature, we may make a series of coils whose resistance is equivalent to that of any number of miles, or fractions of miles. A number of these coils, arranged to be thrown in and out of circuit at pleasure, is termed a *Rheostat*.

"It is sometimes necessary, in measurements, to divert a portion of the current from a galvanometer, to reduce the deflection of the needle within proper limits. In this case, a wire or coil of greater or less resistance is used, which is connected to both posts of the instrument to be shunted. The current will then divide inversely as the resistance of the two paths or routes open to it. Suppose a galvanometer coil to have a resistance of 99 ohms, and the shunt-wire of 1 ohm. Then $\frac{99}{100}$ of the current would pass through the shunt wire, and $\frac{1}{100}$ through the galvanometer.

"In this case, the result shown by the galvanometer must be multiplied by the shunt to obtain the correct answer.

TANGENT GALVANOMETER.

"The intensity of the current, as measured by the tangent galvanometer, is proportioned to the tangent of angle of deflection of the needle.

"'Bradley's Improved Tangent Galvanometer' is the only one in use in the United States for line work, and is undoubtedly the most accurate tangent instrument made. We quote the description from Dr. Bradley's pamphlet. The needle is a peculiar one, being composed of 3 or more parallel strips of steel, mounted upon a ring of aluminum, and trimmed to form a circle. Long aluminum pointers are attached to this disk. The needle is balanced upon a steel point, on which rests an agate. The weight of the needle is only 20 grains.

"The coils are so placed that the current runs parallel with the meridian of the needle. They are $\frac{1}{2}$ in. or more wider than the diameter of the disk. By this means all parts of the steel composing the needle are subjected to the same inductive influence in all its deflections.

"It is a condition indispensable in the construction of a true tangent galvanometer, that the current through the coil should act as uniformly upon the needle in all its deflections as the earth's magnetism does; a narrow coil under a long needle does not fulfil this condition; for, as the extremities of the needle in its deflections pass more and more away from the coil, the inductive influence is less and less, as compared with the earth's influence.

"On the contrary, if we place a very broad coil under a long needle, the same difficulty occurs, but in the opposite direction. While the needle is on the meridian it is under the influence of but few convolutions, in the middle of the coil, but as it deflects it comes under the influence of an increasing number of convolutions, and therefore the influence is more and more increased.

"It being evident that the truth lay between these extremes, the expedient of a needle in the form above described was resorted to, and with entire success, for in this the condition sought is accurately fulfilled.

"Coil No. 1 is composed of very fine copper wire, wound evenly back and forth over the whole width of the coil, and of a sufficient number of layers to give a resistance of 150 or more ohms.

"Coil No. 2 is of 30 wire wound in the same manner, and to twenty-five or thirty ohms resistance. No. 3 is of two layers of No. 23 wire, giving one to two ohms resistance. And No. 4 is a strip of sheet copper of the width of the coils, and wound three and a half times around, so that the cur-

rent passes four times under the needle; the resistance of this may be considered as null, or not sufficient to be noticed or taken into account.

"The outer ends of all the coils are connected with a common screw-cup, while the inner ones are connected each with its cup bearing its proper number.

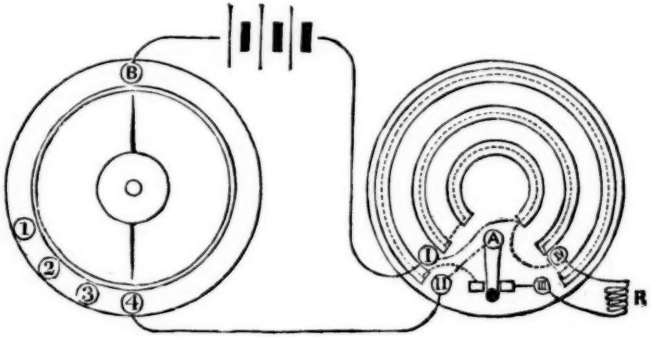
"Coil No. 1 is for currents of high intensity, No. 4 for those of great quantity, and Nos. 2 and 3 are for mixed or intermediate currents.

"The Rheostat contains coils whose several resistances range from $\frac{1}{100}$ of an ohm to 4,000 ohms, any one or more of which may be thrown into the circuit by removing the proper plug or plugs on the top of the rheostat, so that any resistance may be introduced from $\frac{1}{100}$ of an ohm to 10,000 ohms.

"In addition to two screw-cups [I. and II.] for connection with the battery and galvonometer, there are two other screw-cups [III. and IV.] for connection of any conductor whose resistance it is intended to measure; also a switch, A, on the rheostat, so arranged that the battery may be thrown through the rheostat or the conductor.

"Connections for Measurement.—Connect line or instrument-wires to be measured, to posts III. and IV. of the rheostat, one pole of the battery to B, on the galvanometer, and the other to I., on the rheostat. The wire leading from II. of the rheostat, is connected with 1, 2, 3, or 4, of the galvonometer, depending upon the coil to be used. Push the switch A to the right, throwing the current through the wire to be measured. Note the deflection of the needle. Now push A to the left-hand

Fig. 1.



plate, throwing the current through the rheostat. Remove plugs, thus letting resistance into circuit, until the needle shows the same deflection. Add the figures marked on the holes unplugged, and you have your resistance in ohms.

"When you measure a wire put to ground at distant end, connect as before, except that you put a ground-wire to post IV. and line to III. Manipulate as before.

"Testing for Insulation.—First unplug 10,000 ohms resistance, using galvanometer coil No. 1. Note the deflection with the current through the 10,000 ohms. Call this the 'maximum of the galvanometer.' Now switch to the line (which is open at the farther end), and note the deflection again. (The better the insulation of line the less the deflection.)

"Suppose the deflection with the 10,000 ohms of the rheostat to be 30 deg., the tangent of which is .5774 *, while that through the line is 10 deg., the tangent of which is .1763.

"Now the tangent .5774 is to 10,000 ohms, as the tangent .1763 inversely is to the answer; or,

$$\frac{.5774 \times 10{,}000}{.1763} = 32{,}751 \text{ ohms.}$$

the insulation resistance of the line. This, multiplied by the number of miles, gives the mileage insulation, and this again, by the number of insulators per mile, the average resistance of each insulator.

"We give the above examples to show the method of using the instrument. Many of the formulæ given in this book may be

* See table of tangents.

used for various measurements with this instrument.

GAUGAIN GALVANOMETER.

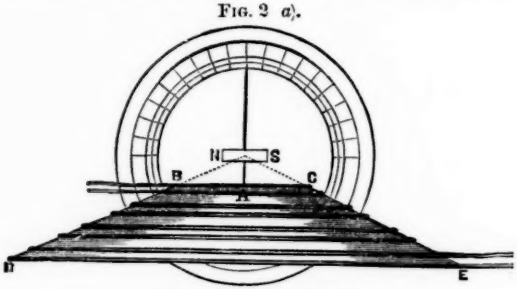
"This is also a tangent instrument, useful for measuring the electromotive force of batteries, their quantity and internal resistance. Its construction is in accordance with the following law:

"If a magnetized needle is submitted to the action of a circular current, placed in a magnetic meridian, when the centre of the needle occupies the summit of a cone, having for its base the circular current, the tangents of the angles of the deviation of the needle will be nearly proportional to the force of the current, when the height of the cone is equal to one-fourth of the diameter at its base. This theorem is correct within $\frac{1}{130}$, when the needle is from 1.17 in. to 1.36 in. in length, and the coil not less in diameter than thrice the length of the needle."

"Fig. 2 (*a*, *b*) gives a plan and an elevation of this galvanometer.

"The wire forming the helix is generally

FIG. 2 *a*).



PLAN OF GAUGAIN GALVANOMETER.

wound in two parts of equal length and resistance, thus having an equal effect upon the needle. Thus this galvanometer may be used with both coils connected, and the indication given by the deflection as in a tangent instrument, or the resistance to be measured, may be connected with one-half, and a rheostat with the other, using it as a differential instrument.

DIFFERENTIAL GALVANOMETER.

"In this form the needle is acted upon by two coils of equal length, resistance and power. The current leads to the coils on one wire, where it divides, passing around the needle in opposite directions. The resistance to be measured is attached to one coil, and the rheostat to the other. When the same amount of resistance is let into circuit in the rheostat, or its equivalent by shunting (see shunt), the effect upon the needle will be the same in each direction, and the needle will be brought to zero. Then the resistance shown in the rheostat (multiplied by the shunt, if one is used) gives the required information.

WHEATSTONE BRIDGE.

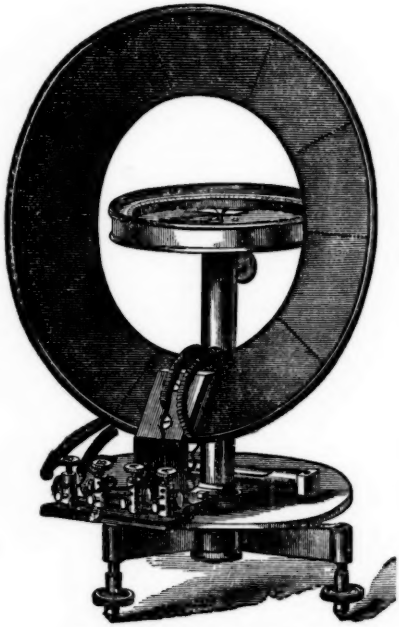
"In tangent and differential galvanometers the effect upon the needle is proportioned to the strength of the current, this being controlled, of course, by the resistance in circuit. The Wheatstone Bridge system of measurement is entirely different, its action being based upon the fall of tension of the current.

The fall of tension of a current from the pole of the battery to the wire terminal at the ground is, as we have shown, uniform. If, for a portion of the distance, we use two wires instead of one, the current will divide and flow by the two branches, and a point on one wire may be connected to a point on the other by a cross-wire, where the tension of the current is the same, without at all affecting the flow of current on the two lines. For, as the flow of current is caused by a difference of tension between the battery and the point with which it is connected by the line-wire, and as the tension of the currents at the two points on the wires connected by the cross-wire is the same, no current will flow through the cross-wire. And a galvanometer inserted in this cross-wire will, of course, show no deflection.

"In Fig. 3, suppose the current to start from E and flow to post 1. Here it divides, one-half passing by wire A, 3, B, to 2, and the rest by C, 4, D, to 2, and thence the

current returns to battery. The resistance of the sides A and C, and B and D, being alike, the tension of the two portions of the current, at 3 and 4, is the same, and no current will pass across, from 3 to 4, through the galvanometer.

FIG. 2 (*b*).



ELEVATION OF GAUGAIN GALVANOMETER.

"Again: suppose we insert at A a resistance of 10, at B 100, at C 500, and at D 5,000. We shall find that the needle on the cross-wire still refuses to deflect. Because the current divides at 1, inversely as the resistance of the two routes 1, A, 3, and 1, C, 4; and the resistance at C being 50 times as great as at A, 50 parts of the current passed through A, with a resistance of 10, while 1 part passed through C with a resistance of 500. The tensions of the two portions, on arriving at 3 and 4, are the same, and as the same proportion as between A and C, is found between B and D, the divided portions pass on until they join at 2 and return to battery. Therefore, when A bears the same proportion to C, that B does to D, or when A : C : : B : D, no current will pass between 3 and 4.

"Now let us measure an unknown resistance which we will insert between the binding posts at D. Say we put 20 ohms in at C, and 1 at A. The needle is deflected strongly. Now insert resistance at B until the needle comes back to zero. Say it requires 250 units.

"Then,

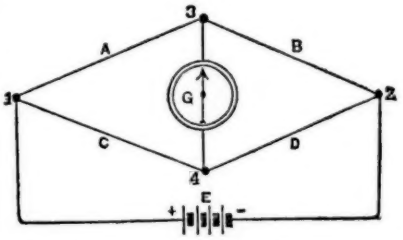
$$\frac{20 \times 250}{1} = 5000,$$

which is the resistance at D.

"If the resistance to be measured is small, you may insert equal amounts at A and C, and then the number of units inserted at B will exactly equal D.

"There are two forms of galvanometers in this country, made on the above principle: Siemens' and Gray & Barton's. The latter we will describe first, as its arrangement is similar to the diagram, Fig. 3.

FIG. 3.



"The battery-wire is led to a brass plate, on each side of which are smaller plates connected with resistance coils. By inserting plugs on each side of the battery-plate, the proportions of resistance between the first and second sides of the bridge (A and C, Fig. 3) may be varied at pleasure. The resistance to be measured is introduced at D, and a rheostat box at B.

"The Siemens galvanometer is entirely different in appearance, and although not as accurate as the Gray & Barton for small measurements, is much more convenient for general line-work, as it is portable, light, and convenient in form.

"The needle is made astatic. That is, two light needles are affixed rigidly to the same shaft. The two needles are polarized in different directions. One being slightly stronger than the other, the working effect or polarity of the pair is the difference in strength between them. This being very slight, the tendency to remain in the magnetic meridian is very feeble, and an extremely weak battery current will cause a

deflection. To increase still more the sensitiveness of the needle, it is suspended by a single fibre of untwisted cocoon silk. The lower needle hangs inside the coil, while the upper, which serves also for an indicator, hangs across the top of the dial. The dial and needle are covered with a glass case; surrounding the base of the glass horizontally is a slate disc, divided into 300 deg., running 150 from each side of the centre or 0 mark Half embedded in the edge of this slate is a platinum or German-silver wire. This wire forms the first and second sides of the Wheatstone bridge—the A and C of Fig. 3.

"Pressing against this wire is a small platinum wheel with a vernier, on a movable arm. To this the battery-wire is connected. In the base of the instrument are three resistance-coils, 10, 100, and 1,000, either one of which is let into the third side (B, Fig. 3) by removing the plug which cuts it out. The resistance to be measured is introduced into side 4 (D, Fig. 3).

"The principle of measurement is precisely like that shown in Fig. 3; but in the Siemens, sides B and D being fixed, you vary the proportion between A and C until the proportion of the latter two is the same as the first two.

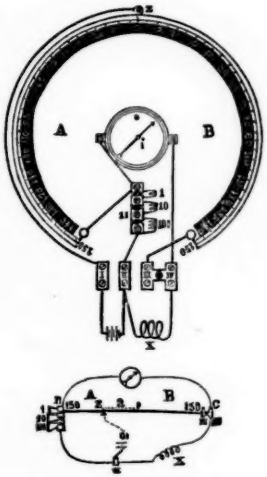
"The slate being divided into two parts by the divisions of 150 each, one side is marked A and the other B. Fig. 4 will show the connections. To measure the resistance of a relay, for instance, we connect the battery to posts I. and II., and the wires from the resistance to be measured to posts II. and IV. The plug remains in, between III. and IV. Remove the plug at 100.

"The current passes from post I. to roller Z. There it divides, one portion going by the wire on the edge of the slate, through the resistance coil 100 back to battery, by post II. The other portion of the current passes (on the B side of the slate) to posts III. and IV., thence out through the relay to be measured, and back to battery at post II.

"Remember, that the wire between the roller Z and 150, on one side of the slate, is the first side (A, Fig. 3); that between the roller and 150 on the opposite side corresponds with the second side (C, Fig. 3); the resistance 100 to post II., the third side (B, Fig. 3); and from post IV., through the relay to be measured, back to post II. (D, Fig. 3), is the fourth side; while from C, through the galvanometer, is the cross or bridge-wire.

"Now, when by moving the roller Z to the left or right, the proportion between the sides of the slate, A and B, is the same as between the resistance 100 and the relay to be measured, the needle will come to zero.

Fig. 4.



"Suppose that when the needle stands at 0, the wheel Z is at 50, on the A side of the slate. Then, as A is to B, so is 100 to X, the unknown resistance. There are 150 deg. on each half of the slate. Then the formula would read,

$$\frac{150 + 50}{150 - 50} \times 100 = X, \text{ or } \frac{200}{100} \times 100 = 200,$$

which is the resistance sought.

"When a line is to be measured, connect battery to post I., ground to II., and line to IV. The ground on post II. completes the circuits, as the line is grounded at distant end, and the other end of the battery is also grounded.

SINE GALVANOMETER.

"The strength of the current, in a sine galvanometer, is proportional to the sine of the angle of deflection. The Siemens may be used as a sine galvanometer by connecting the battery to post II., and line to be measured to IV., and unplugging between III. and IV. Set the needle in position; put the vernier-wheel at 0, on the slate.

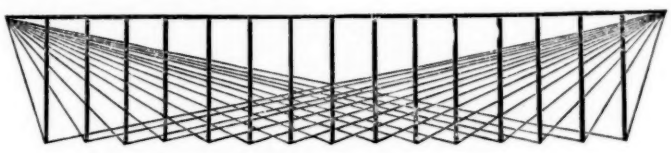
Now, when the needle is deflected, move the needle-coil by revolving the slate in the direction of the deflection of the needle. The coil is thus kept parallel with the needle, and its maximum effect exerted. When the needle is deflected to that point where the earth's attraction for the needle is exactly balanced by the effort of the coil-current to deflect it, the needle will become stationary. Now read the degree on the slate opposite the vernier, and a reference to the table of sines will give the sine of the deflection; and having previously taken the constant of your instrument—that is, having found to what sine it will deflect with a given resistance and a given battery—you have now a proportion giving you the result sought."

SOME OPEN QUESTIONS IN BRIDGE BUILDING.

Contributed to Van Nostrand's Magazine, by FREDERICK H. SMITH, C. E.

I.

The chord strain in a Bollman truss is determined by Molesworth in England, and Shreve and others in America, by the well-known formula $\frac{L\,W}{8\,D}$ = strain, uniform throughout the length of the chord, while Vose, Whipple, and others add together the horizontal resultants of all the tie strains, both main and counter, that pull against one end of the chord. That there is a great difference in the results of these methods, is best shown by a few figures, taking Shreve's Bollman truss example, shown on page 325, *et seq.*, of his treatise on "Bridges and Roofs," deck span 160 ft. long $\times$ 15 ft. deep, in 16 panels of 10 ft. each, gross load 240 tons or 15 tons per panel, two trusses in one.



In this truss the Molesworth and Shreve method gives, page 326,

$$\frac{240 \text{ tons} \times 160 \text{ ft.}}{8 \times 15 \text{ ft.}} = 320 \text{ tons chord strain,}$$

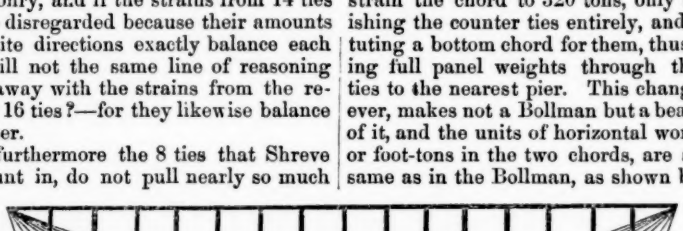
while the method of Vose and others gives

15 tons	$\times \frac{15}{16} \times \frac{10}{15}$	= 9.375	tons	chord	strain.
+ " "	$\times \frac{14}{16} \times \frac{20}{15}$	= 17.5	"	"	"
+ " "	$\times \frac{13}{16} \times \frac{30}{15}$	= 24.375	"	"	"
+ " "	$\times \frac{12}{16} \times \frac{40}{15}$	= 30.0	"	"	"
+ " "	$\times \frac{11}{16} \times \frac{50}{15}$	= 34.375	"	"	"
+ " "	$\times \frac{10}{16} \times \frac{60}{15}$	= 37.5	"	"	"
+ " "	$\times \frac{9}{16} \times \frac{70}{15}$	= 39.375	"	"	"
+ " "	$\times \frac{8}{16} \times \frac{80}{15}$	= 40.0	"	"	"
+ " "	$\times \frac{7}{16} \times \frac{90}{15}$	= 39.375	"	"	"
+ " "	$\times \frac{6}{16} \times \frac{100}{15}$	= 37.5	"	"	"
+ " "	$\times \frac{5}{16} \times \frac{110}{15}$	= 34.375	"	"	"
+ " "	$\times \frac{4}{16} \times \frac{120}{15}$	= 30.0	"	"	"
+ " "	$\times \frac{3}{16} \times \frac{130}{15}$	= 24.375	"	"	"
+ " "	$\times \frac{2}{16} \times \frac{140}{15}$	= 17.5	"	"	"
+ " "	$\times \frac{1}{16} \times \frac{150}{15}$	= 9.375	"	"	"
Total.....		425.			

Here is a difference of 105 tons of chord strain. Shreve explains his analysis on page 326 by saying: "Taking moments around a point in the centre of the truss, and in the line of the lower ends of the vertical braces, the strains in the inclined braces crossing the centre may be disregarded, as their amounts in opposite directions exactly balance each other." It is true enough that they do exactly balance each other, but it is not so clear that they may therefore be disregarded, as they can only strike that balance by pulling against each other through the chord, in precisely the same way that the balance is struck by those which do not cross the centre. The truss in question is in no sense a continuous beam, but simply an assemblage of independent triangles, in this case 15 in number, each triangle a complete truss in itself, exerting a chord strain for itself, as though there were 15 separate chords, side by side, in the span. There are thus 30 ties (or inclined braces) in the span, 15 at one end of

the chord balancing 15 at the other, while Shreve's method only allows chord material for 8 ties at each end, thus leaving 7 ties at each end to pull against each other, but with no chord material to transmit their strains. When the span is loaded all the ties in it are at work at once, and if these 7 do not pull against the chord, what do they pull against? There is no anchorage to the masonry, and if the strains from 14 ties are to be disregarded because their amounts in opposite directions exactly balance each other, will not the same line of reasoning also do away with the strains from the remaining 16 ties?—for they likewise balance each other.

And furthermore the 8 ties that Shreve does count in, do not pull nearly so much as even the 320 tons given by the centre formula. They will not work by the process generalized in the phrase, "taking moments around a point in the centre," so long as the counter ties continue to carry to the farther pier, so much of each panel weight as is due to the leverage of the span at each post, *i. e.*, so long as the truss is a Bollman truss, but they can be made to strain the chord to 320 tons, only by abolishing the counter ties entirely, and substituting a bottom chord for them, thus throwing full panel weights through the main ties to the nearest pier. This change, however, makes not a Bollman but a beam truss of it, and the units of horizontal work done, or foot-tons in the two chords, are still the same as in the Bollman, as shown below.

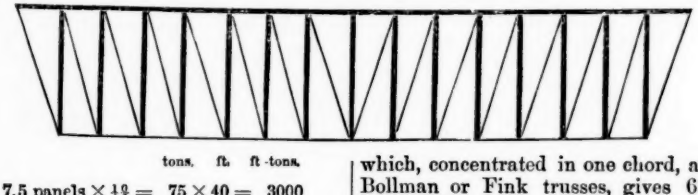


15 tons	×	$\frac{10}{160}$	= 10 tons	× 140 ft.	= 1400 ft.-tons.
"	"	× $\frac{20}{160}$	= 20 "	× 120 "	= 2400 "
"	"	× $\frac{30}{160}$	= 30 "	× 100 "	= 3000 "
"	"	× $\frac{40}{160}$	= 40 "	× 80 "	= 3200 "
"	"	× $\frac{50}{160}$	= 50 "	× 60 "	= 3000 "
"	"	× $\frac{60}{160}$	= 60 "	× 40 "	= 2400 "
"	"	× $\frac{70}{160}$	= 70 "	× 20 "	= 1400 "
7.5 "	×	$\frac{80}{160}$	= 40 "	×	
Top chord str'n			= 320 "	× 160 "	= 51200 "
				Total units of work	= 68000 "

which, if concentrated in one chord, gives

$$\frac{68000}{160} = 425 \text{ tons strain.}$$

This leads to a statement, which the writer believes has not been heretofore made, viz., that so long as the same panel data are preserved, the units of work done horizontally, or foot-tons, are the same in all systems of trussing, which fact affords a valuable check, and as such is submitted to the profession. In proof of its accuracy, the Fink truss, given by Shreve, page 332, is cited, in which the chord strain is shown to be 425 tons, using same data as the Bollman, referred to above, and, in further support, the chord strains of a simple quadrangular beam truss, reduced to foot-tons, are here given.



Tons.				tons.		ft.	ft.-tons.
15 ×	7.5 panels	×	$\frac{10}{160}$ =	75	×	40 =	3000
" ×	14.0 "	×	" =	140	×	" =	5600
" ×	19.5 "	×	" =	195	×	" =	7800
" ×	24.0 "	×	" =	240	×	" =	9600
" ×	27.5 "	×	" =	275	×	" =	11000
" ×	30.0 "	×	" =	300	×	" =	12000
" ×	31.5 "	×	" =	315	×	" =	12600
" ×	32.0 "	×	" =	320	×	20 =	6400
				Total units of horizontal work =			68000

which, concentrated in one chord, as in the Bollman or Fink trusses, gives 68,000÷160=425 tons chord strain. In fact, the centre formula applied to a truss with but one chord, covers only a king-post truss of but two panels, in which two half panels rest directly on the piers, leaving only one-half of the gross load to be carried by the truss to the piers. In this 160-ft. span, 2 panels of 80 ft. do not form a practicable bridge, and intermediate supports must be

provided. The centre formula only contemplates carrying $\frac{8}{16}$, while the Bollman carries $\frac{15}{16}$ of the gross load. These $\frac{7}{16}$ of difference can be supported by Fink's system of secondary triangles, or the whole 15 by Bollman's primary triangles, or by any form of trussing, and the units of horizontal work will still remain the same so long as the same panel data are used, or, in other words, so long as the same conditions of leverage are preserved by supporting the gross load at the same points and from the same depth.

Again, a truss is strictly a machine, at work carrying a load, and in it the law of equality between action and reaction is in full force! Tension must equal compression under an uniform load. The units of work or foot-tons in the hypothenuse of the right-angled triangles, into which all trusses are resolvable, must equal those in the base and altitude as inevitably as their foot-feet or squares, and their itemized account must balance. When compression exceeds tension in the chords, there is a corresponding excess of tension in the web system, and *vice versa*. To apply this to Shreve's Bollman truss, it is only necessary to multiply the tie strains given by him on page 328 by their respective tie lengths, giving 71,375 foot-tons of tension in the hypothenuse, from which deduct 15 tons $\times$ 15 ft. $\times$ 15 posts = 3375 foot-tons compression in the altitude, leaving 68,000 foot-tons compression in the base, which, divided by 160 ft., gives the same 425 tons chord strain we had before.

It seems clear, then, that the true strain in this 160-ft. span, is 425 tons instead of 320, and in view of the recent expiration of the Bollman patent, it is well to realize that the difference in strain is important in both a professional and business view. A chord proportioned by the Molesworth and Shreve analysis to carry 320 tons, at 4 tons per sq. in., with 5 for factor of safety, will contain 80 sectional inches. These 80 in. will really have to resist 425 tons of strain, or 5.3 tons per sq. in., at best a very unusual strain and one which cuts the factor of safety down to 3.8. The difference of 105 tons between the chord strains, at 4 tons per sq. in., represents 26 sectional inches, or say 90 lbs. of wrought iron per lineal foot of bridge, which, at 10 cents per pound erected, is $9 per foot, or about 10 per cent. of the ordinary contract price of the span in question. This sum is always decisive of fair competition between structures of equal merit, and is a larger per cent. than is ordinarily found on the cheerful side of the annual balance sheets of reputable contracting engineers.

THUNDERSTORMS AND STRUCTURES.

From "The Building News."

The Leipzic Academy of Sciences have appointed a commission to investigate the means adopted, and the results historically ascertained, with reference to the protection of buildings from the effects of lightning. They have been considering the dictum, proclaimed some years ago, of a civil engineer, who d clared that "Science has every reason to dread the thunder-rods of Franklin; they attract destruction, and houses are safer without than with them." Now this is a theory which admits of being otherwise than scientifically treated. What do the records say? They assure us, that, in a majority of instances, the electricity of the cloud is drawn quietly down into the earth, so long as a good conductor is present; but whenever this becomes faulty, whenever it is interrupted, its destroying powers accumulate with terrible rapidity, and no other power known is so swift and fearful in its work of annihilation. The public, however, are very much in the dark with reference to this subject. It is, as a rule, more alarmed by the roar and rattle of thunder than it is by the flash of lightning, whereas the former is perfectly innocuous after the latter has passed. And the eccentric course followed by the electric fluid is constantly unappreciated. Thus Professor Henry tells us of an instance in which the lightning struck the top of a chimney, passed down inside the flue to a point opposite a mass of iron placed on the floor of the garret, where it pierced the chimney, breaking the plaster and burning the laths of the ceiling; then leaping, so to speak, into a bed chamber below, seizing hold of a copper wire, and travelling along it to another floor; next bursting through a dormer window, which fell, dashed to atoms, upon the pavement, and, finally, vanishing up a leaden gutter.

There was a man asleep in bed close by where it passed, and he never noticed the phenomenon. According to Sir William Snow Harris, who contradicts in this respect, the civil engineer we have referred to, a good conductor would have carried down the discharge without any danger or destruction whatever. It is known that on last Sunday evening balls of fire, and what is popularly called wildfire, exploded in the sky; and we have a chronicle indicating a similar wonder in the ruin wrought at S. Michael's Church, Blackrock, near Cork, in January, 1836. The spire was constructed of limestone, strengthened by iron bars and cramps within and without. The local record runs: "The fabric was seamed from the summit to the bottom by one gaping, jagged rent, 5 yards in width, and yet the wall might have been mistaken for that of a fortress." There was no protecting-rod. The Commission nominated at Leipsic undertakes to collect and compare the instances in which this apparatus has been employed with success, and where it has failed to answer its purpose. It can only decide upon historical evidence, of course; but an abundance of this is at hand. The ship Thisbe in 1816, unprovided with a conductor, was set on fire and nearly wrecked, in a thunderstorm; the electrical discharge struck her mainmast, swept her decks, flew from gun to gun, and reduced her fabric to a ruin. The Bayfield, also destitute of a conductor, was smitten, in 1845, from her deck to her hold, and totally destroyed. The Poland, five years earlier, was completely burnt out and blown up. On the other hand, the New York, an American packet, supposed to have been perfectly fitted, was struck as if by a broadside of cannon-balls; her bulwarks and spars ignited, her mast-head and cap took fire, her cabin furniture was shattered; all the watches worn by persons on board were stopped; the knives and forks in the steward's pantry were dangerous to touch, and yet the lightning-conductor rose 2 ft. above the top of the mainmast, and descended deep into the water. Turning to structures on land, we have the example of a house mentioned by Professor Henry. The electric fluid struck the summit of the chimney, it went down the flue, but was stopped by a block of iron on the floor of a garret; thence, however, in a second or two, it resumed its course, and exploded in a cellar, reappearing, in a most mysterious manner, from a cock-loft in the roof. We have testimony, moreover, to the effect that bell-wires are often perilously attractive to lightning. It is well ascertained, also, that the lines of the electric telegraph have frequently conveyed terrible shocks during the violence of a thunderstorm. They have on extraordinary occasions, actually evaporated beneath this irresistible influence. At Newbury, a steeple was hit, and the iron-work in it disappeared as though it had never existed. Faraday says he saw a dwelling in Westminster whence every trace of bell-wire, after a thunderstorm, had vanished. These are notes which it is important to remember, since they may lead to some reconsideration of a system upon which we rely too confidently, perhaps, for the safety of our habitations. A good authority, among others, remarks, after citing too many illustrations for us to quote: "In all the foregoing cases it will be observed that the metal chains, rods, and wires were not of sufficient size to convey away the charge of lightning; but being delayed in its progress, the astonishing heating power of the electric fluid had sufficient time to burn or fuse away the combustible metal. But, according to Sir W. S. Harris, quoted by the same authority (Mr. Tomlinson), "a copper rod of three-quarters of an inch in diameter would be sufficient to withstand the heating effect of any discharge of lightning whose destructive effect has ever been recorded." That, however, remains a question among the foremost men of science, and we are only tentatively putting it. Some buildings are fitted with two conductors of unequal proportions, which create the danger of the lightning passing from the smaller to the larger, penetrating through everything on the way. Even a nail in the floor has been known to divert its flight; it will go down against the smoke of a chimney; it will glance along the gilding of a picture-frame; it will hang about the hinges of a door, and this, in fact, as Rittenhouse asserts in the American Philosophical Operations, within 50 yards of a conductor, constructed and placed upon universally-approved principles. But the loss of human life, after all, through these ebullitions of nature, is comparatively slight. The famous case at Naples may be recollected. Lord Tilney was entertaining an assemblage of nearly 500 persons; the lightning attacked his palace. It melted, corroded, or blackened the gilding of the roof,

the cornices, the ornaments of the chairs, and yet it traversed nine crowded rooms without injury to a single individual. However, although, as we have mentioned, the bolt will quit a small conductor for a larger one, it will occasionally, through some caprice of its nature, or, we should rather say, in obedience to some natural law not yet adequately understood, abandon the largest for a mere wire, or even be stopped in its descent by a gun-barrel. Some curious anecdotes in the chronicles of thunderstorms are related. That was a formidable storm which annihilated 85 ft. of the magnificent spire of S. Bride's, near Fleet street, erected by Sir Christopher Wren. The lightning struck an iron bar, which carried it safely down so far as itself extended; but then, the conductor ceasing, the masonry flew in all directions; several enormous blocks of stone were shivered into powder; others were almost melted; a few were blown to a distance, as if by an explosion. It would have been better in this instance had there been no conductor at all. The circumstances of S. Martin's Church, damaged in 1842, were almost precisely similar. The top of the vane-spindle was first struck; thence the lightning passed down the iron rod, without doing any injury, until the iron rod ended, and the fluid darted about from one iron-clamp strengthening the masonry to another. It burned the wood; it melted lead; it flashed upon the clock-dials, scorching them out of recognition; and it burst in the clock-room like a blast in a mine. Still, as we have said, the human mortality from lightning is not generally on a large scale, and might be very much reduced by precautions on the part of builders. Arago estimated that the number of deaths from this cause amounted in France to about 70 in the year; Bondin calculated that from 1835 to 1852, 1307 so perished; none in November, December, January, and February; but most in June and August. The lowest rate is assigned to Belgium, and the next to Sweden, the United States and England being about on a par. As a rule, however, these fatalities do not occur inside a structure of any kind. The peril, as experience shows, is less in a crowded town than in a village or in the open country, and, naturally, the more elevated structures are the most liable to be struck. Fuller, indeed, in his "Church History," asserts that there scarcely ever existed a great abbey in England which had not been, at one time or another, wholly or partially destroyed by lightning, and his citations, taken in comparison with the records of our own times, are certainly remarkable. In all cases it is the spire, the tower, and the dome which has been mutilated. As to ordinary habitations, all sorts of theories are in vogue on the subject of danger and safety. Some rely on thick glass in the windows, and some on register stoves; others recommend stone roofs instead of slate, and others tell timid people that they should live in a hollow. It is contended on this side that there should be the least possible admixture of metal in the combination of an inhabited structure; and on that, that all the bells beneath the roof should be kept continually ringing, just as, in obedience to an old superstition, cannon are fired at sea. The mass of evidence upon this topic points, however, to the one conclusion already suggested, that a good lightning-conductor is the solitary safeguard, but that, unless good, it is worse than none.

ECONOMY OF FUEL.

From "Engineering."

The "Revue Universelle des Mines" some little time ago published a series of valuable papers on the subject of the "Economization of Fuel," from the pen of M. Paul Charpentier, in which the author strongly insists upon the advantage of using fuel of every description in a gaseous state and under a constant pressure.

His arguments in support of this may be briefly stated as follows:

That combustion—employing the word in its ordinary industrial acceptation—may be what is termed perfect or complete, it is essential that the following conditions be satisfied:

1. The combustible and the supporter of combustion must be intimately intermixed.

2. These bodies must be in the same physical state, in which case alone the first-named condition is attainable.

3. They must be brought into contact at

the temperature best suited to their complete combustion.

4. With a like object a sufficient surface must be given to the flame.

5. The relative proportions of the combustible and the supporters of combustion must be exactly those requisite to complete combustion.

These conditions, M. Charpentier asserts, can be best satisfied by a system proposed by him, which is stated to be applicable to fireplaces of every class and description. The remarks in the "Revue" apply chiefly to the furnaces employed in industrial processes and for locomotive purposes.

To show the defects of the methods now in use, M. Charpentier institutes a comparison between the theoretical and the actual calorific power of ordinary coal.

Taking a coal of the following composition:

	kilog.
Pure carbon	65
Ash	5
Hygroscopic water	5
Tar	5
Illuminating gas	20
	100

he shows that according to the calculations of MM. Favre and Silbermann, and of M. Regnault, and asssuming the whole of the heat to be utilized, we have 8,038 calories per kilogramme as the calorific power of the coal. Each kilog. of this coal would, accordingly, evaporate 12.618 kilog. of steam at a pressure of 1 atmosphere. This is the calorific power in theory. In practice he asserts that the result is about 3 kilog. of steam for each kilog. of coal burned.

The causes of the waste of heat—and consequently of fuel—herein implied in the furnace of ordinary steam boilers he shows as follows:

1. Loss of heat occasioned by the pressure of atmospheric air in greater volume than is requisite to perfect combustion.
2. Loss of heat through the chimney.
3. Loss of heat by smoke.
3. Loss of heat by cinders.
5. Loss of heat in the evaporation of the 48 kilog. of hygroscopic water contained in every 100 kilog. of coal of the above description.
6. Loss of heat by radiation from the under surface of the fire-bars and other portions of the furnace.

In regard of the first, grouping the combustible constituents of the coal aforesaid, we have:

	kilog.
Carbon total	82.39
Hydrogen total	4.73
Sulphur total	0.188
	87.308

The total volume of oxygen requisite to convert the above into CO^2, HO, and SO^2, would be 257.7 kilog. Reducing this by the proportion of oxygen contained in the illuminating gas, we have still 256.28 kilog. of oxygen required, which supposes the presence of 1,114.30 kilog. of atmospheric air occupying a space of 861.7 cubic metres at a temperature of 0 deg. Cent.

But the presence of the fire-bars will not allow us to give the amount of air thus required in theory. The bars impede the free contact of the air with the fuel, and to feed the fire it is found necessary in practice to increase the size of the air passage and the velocity of the draught. Most writers recommend a constant supply of air of double the volume requisite in theory. And even then combustion is very incomplete. The temperature of the gaseous products and of the heated air on entering the chimney varies greatly; but in all cases the loss of heat thus occasioned is very considerable; in certain industrial processes, as puddling, etc., and in locomotives driven at express speed, the loss is enormous. As a very reduced average M. Charpentier assumes the waste of heat thus caused at 16 per cent. of the whole. Again, as regards the chimney itself. Some writers content themselves with the assertion that the chimney carries off in waste 25 per cent. of the heat produced by the fuel. And this assertion will admit of rigorous demonstration. Employing the foregoing data, and assuming the temperature of the gases on entering the chimney to be 500 deg. Cent., it can be proved that a loss of 18 per cent. is incurred, without taking account of the specific heat of the gases which are thus allowed unlimited expansion, or of the imperfect manner in which combustion is accomplished, or of the heat carried off by the carburets of oxygen and hydrogen contained in the smoke, whose capacities for heat far exceed that of atmospheric air.

It may, therefore, be concluded that it is of great importance to deprive the gaseous products of combustion of their heat before they enter the chimney, as well as to avoid the influx of atmospheric air in greater

volume than is absolutely necessary to complete combustion.

Again, in the matter of smoke. The great smoke question, M. Charpentier observes, has formed for many years the theme of animated discussion. Many inventions have appeared, but none, as yet, have satisfactorily achieved the desired end. This has arisen from the fact that the inventors have confined themselves to a narrow, one-sided view of the matter. Many persons regard the subject—sanitary considerations apart—as of trifling moment; others have attached an exaggerated degree of importance to the consumption of the smoke, but without recognizing its bearings on the question of economy in fuel.

Five conditions have been enumerated above as essential to perfect combustion. Practically, very few of these conditions are satisfied by the arrangements now in use. The combustible—the coal—and the supporter of combustion—the oxygen in the air—cannot be brought into the requisite state of intermixture, as their physical states are dissimilar. Conditions 3 and 4 are satisfied at best by haphazard. Locomotive engines are particularly badly arranged in this respect; combustion in them is, accordingly, very incomplete, and their chimneys belch out clouds of the densest smoke.*

Now, the disadvantages of smoke are twofold: 1. It is insalubrious and a public nuisance. 2. It occasions a waste of fuel, and consequently of money, which in some cases is enormous, as few persons who have observed iron works, coke ovens, glass works, etc., pouring forth their sooty clouds, will be prepared to question.

But, smoke may be colorless, and yet carry off in waste the gaseous products of combustion to a very considerable extent. Many analyses have been attempted to determine the amount of unutilized gases contained in smoke. The mean of M. Debette's experiments showed a loss of 9 per cent. from this cause, but the first of these experiments indicated a loss of 24 per cent. Some experiments made in Alsace gave a mean loss of 15 per cent; Ebelmann only got 7 per cent; M. Ser, in a chimney at Thierry, got 40 per cent. These experiments, it should be said, were made with the furnaces of steam boilers. In many departments of manufacturing industry, the loss is far greater; and we shall be within the mark if we take the average under all circumstances at 20 per cent. The loss of heating power by the formation of cinders is often very great, and is also very variable. In locomotives, notwithstanding the narrow openings between the bars, it is of some consequence, as the cinders are not turned to useful account. In certain metallurgical processes, the loss is very great indeed; the fires are constantly stirred, and the imperfectly burned coals fall through into the ash-pit to increase the intense heat which radiates therefrom. In the experiments of MM. Tresca and Silbermann, at Cherbourg, the loss of heating power, owing to the formation of cinders, was found to be 25 per cent. of the total heat produced. M. Charpentier considers that we shall be well within the mark if we take the average at 15 per cent. The waste of heat occasioned by the evaporation of the water contained in the coal and of that produced in the combustion of the hydrogen may be taken as 3 per cent. of the whole. The losses through radiation and the formation of clinkers are smaller and very variable in their amounts.

The total waste of heating power, therefore, stands thus:

	per cent.
Loss of heat occasioned by the presence of an excess of atmospheric air	16
ditto through the chimney	18
ditto by smoke	20
ditto by cinders	15
ditto by evaporation of water in the coal	3.6
ditto by radiation, etc.	variable
	72.6

Say, 73 per cent. as the waste of an ordinary open furnace with natural draught. This is only a general average. In very many cases it is far exceeded.

Applying the foregoing to steam furnaces, we find that in place of 12 kilogrammes, the theoretical amount, only 3.3 kilogrammes of steam are evaporated by each kilogramme of coal; this, be it observed, hardly conveys a correct notion of the actual results, as a good deal of water is often carried off by the steam, thus increasing the weight of the latter. So much for the defects of the arrangements now in use. The waste of fuel thus occasioned, M. Charpentier proposes to reduce by suppressing the chimney altogether, and by consuming the fuel in a gaseous state and under a constant pressure, so that the variations in volume—and consequently in capacity for heat—which are now experienced by the gaseous products of combustion, may be avoided. He notices

* M. Charpentier's experience with locomotives appears to have been of an unusually unsatisfactory kind.—Ed. E.

the various projects for economizing fuel, which have hitherto appeared, under four heads:

1. Revolving grates.

2. Supplementary appliances for the introduction of hot or cold air.

3. So-called "smoke-consuming furnaces," in which steam is injected upon the flame, upon the fuel, or into the chimney.

4. "Gas-stoves," so called.

The more or less complicated arrangements under the first head have been pretty generally abandoned. Those under the second are very nearly useless. It is not, generally speaking, that the air is present in insufficient volume—on the contrary, it is usually in excess—but that it is impossible to give it the requisite degree of intermixture with the incandescent fuel. The additional volume of air introduced tends rather to exaggerate than to diminish the loss of heating power. Those under the third heading are better adapted to the end sought, but the injected steam absorbs heat in decomposing, it increases the loss through the chimney, and costs dear for results that are practically small. The "Thierry" furnace, which is about the best, effects a saving of 10 per cent., but, it is admitted in the inventor's prospectus, that this saving is achieved at an expenditure of 8 per cent. of steam.

Lastly, we have the so-called "gas stoves." The principle of a preliminary reduction to a gaseous state of the fuel is an old one. Its first practical application in France was by MM. Laurens and Ebelmann. Since the researches of the latter, it may be said that no advance has been made, although the question has reappeared in sundry forms.

The most successful recent attempt has been that of M. Siemens. The loss of heat in the case of this gentleman's apparatus is estimated by M. Charpentier at 50 per cent., showing a saving of 20 per cent. over the arrangements in ordinary use.

After a lengthy discussion of the theoretical principles of heating with gas under a constant pressure, M. Charpentier proceeds to describe an apparatus, by which he thinks it is demonstrable that enormous advantages might be realized. He proposes to adapt it to fireplaces of every class. It consists of three distinct parts: 1. A gas generator or gazogene, in which the fuel is brought into a gaseous state. 2. A burner, in which the gas produced in the gazogene is burned. 3. An hydraulic regenerator. The gazogene is of ordinary design, and is supplied with condensed air by some sort of fanner; steam is also injected on the incandescent fuel.

The burner is in the form of a pipe placed in any position required, and connected by a valve with the gazogene. It is so arranged that the burning gases are surrounded by air, which impinges on them at an angle, that can be varied according to circumstances, and to the length of flame required.

The hydraulic regenerator receives from the burner the gaseous *residue* of combustion, and secures the following results:

1. The almost perfect utilization of the sensible heat carried off by these gases, which sensible heat has hitherto been employed only in maintaining the wasteful draught of the chimney. It may be observed, that the necessity of having a draught to assist in the reduction of the fuel is obviated by the employment of condensed air, by which, it is calculated, a saving of 25 per cent. will be effected.

2. The utilization of the heat rendered latent by the evaporation of the water existing in the fuel, and of the water produced by the combustion of the hydrogen in the latter, which latent heat is transformed into sensible heat available for useful application.

3. The economization of the heat hitherto wasted by the unlimited expansion of the gases. The maintenance of a constant pressure prevents any portion of it becoming latent, and thus not practically available.

4. It assists in securing complete consumption of smoke.

5. The water in the regenerator being almost always employed to feed the steam boilers, and being at a temperature of about 100 deg. Cent., the excess of carbonic acid which it contains, becomes quickly separated therefrom, and the calcareous matters held by it in solution in virtue of such excess are deposited in the regenerator, thus securing the boiler against incrustation.

The advantages claimed for his system by M. Charpentier are the following:

1. It may be used with any sort of fuel.

2. It will give greater durability to metallurgical furnaces by getting rid of the excess of oxygen, the chief cause of destructive oxidization.

3. The nature and intensity of the flame may be regulated at will.

4. It may fairly be expected to give not only increased economy but improved results, in iron and steel manufacture.

5. In marine boilers the saving in fuel effected will enable a smaller supply to be carried, others give increased capacity for accommodation or stowage.

6. It gives a higher temperature than any method yet devised.

7. The boilers are saved from incrustation, and the chances of an explosion are thus reduced.

8. The suppression of the smoke is complete. In addition to these direct and indirect advantages we find a total absence of cinders.

Appended to M. Charpentier's memoir is a *procés-verbal* of some experiments made with his apparatus on the Orleans and Rouen Railway, in the month of September, 1872. The results are stated to have been very satisfactory. The saving of fuel in the locomotive employed amounted to 47 per cent., and in one case to 66 per cent. These results, however, appear to us to require confirmation, and M. Charpentier seems throughout his memoir to have exaggerated losses, and to have considerably underrated the results obtainable by other plans than his own.

CLAMOND'S INDUSTRIAL GENERATOR OF ELECTRICITY.

Translated from "Les Mondes."

The easy and economical production of electricity of constant quantity and tension, is still an unsolved problem. Hitherto the attention of those who have attempted its solution has been almost exclusively directed to magneto-electric machines, *i. e.*, those which transform mechanical work into electricity. A great number of these machines have been constructed; among these is that of Gramme, which gives a current in one direction only, a machine which is but a practical realization of the apparatus described by Faraday. All these machines have a capital defect; not one of them furnishes an absolutely continuous current. Besides, their use is limited and very much restrained, for they require a motor of more or less power, which can yield only a small fraction of the theoretic work due to the combustion of charcoal. Add to this that not only the magneto-electric machine, but also the motor, are of high price, and require the continual service of at least one extra workman, and we see that the question is still an open one, and that inventors need not look in this direction for the realization of the industrial production of electricity.

The same may be said of hydro-electric piles. True, these furnish a continuous current, though not constant, but they are very expensive to run.

Since Seebeck's discovery there have been many attempts to construct thermo-electric piles of sufficient tension and quantity to displace the ordinary piles.

Messrs. Edmond Becquerel and Marcus have constructed thermo-electric piles, giving remarkable results, when compared with those attained by Seebeck. Those of Becquerel, composed of bars of sulphuret of copper, gave a current of strong tension but small quantity; those of Marcus produced a considerable quantity of electricity. More recently MM. Mure and Clamond, having observed and studied the thermo-electric qualities of galena, constructed with this ore thermo-electric generators of great and remarkable power. In the disposition and use of the elements, the pile was converted into a furnace, employing coke or gas in an economical way. But at first the result desired was not attained. The defect was that which is common to all thermo-electric piles previously inverted, viz., the rapid weakening of the current, especially when employed for actual and continuous work. After these fruitless essays it became an admitted opinion that such piles have no durability; that after a few hours, or, at most, days of action, the interior resistance increases and the current diminishes, so as to become almost null. It therefore became necessary to remove this fatal defect.

Availing himself of the knowledge gained by repeated experiment, Clamond has at last succeeded in solving the problem. He has constructed an apparatus which leaves nothing to desire, either in respect to performance or durability.

Our colleague, F. Michel, has made experiments upon this pile during the last ten

months. From these numerous and carefully-conducted experiments the conclusion is drawn, that the electro-motive force and the resistance of couples do not experience the least variation under the action of heat at a constant temperature. More than this, successive heatings and coolings do not alter the qualities of the elements, affecting neither electro-motive force nor resistance. This result has never before been attained.

In the old galena piles Michel had observed that the passage of the electric current caused decomposition of the ore, and consequent variation in structure, interior resistance and electro-motive force; that the decomposition showed its progress by striæ, so that after a time unequal dilatations ensued, followed by splitting of the bars. With Clamond's new elements, all these defects are absolutely removed, the chemical and molecular condition remains exactly the same for an indefinite period.

While the hydro-electric pile has remained of the type created by Daniell and Grove, and the magneto-electric machines have given unsatisfactory results in spite of ingenious combinations, a new electricity has grown up in a modest and quiet way. To-day thermo-electricity takes its place as a new element in aid of science and industry.

Clamond's apparatus serves every purpose. It furnishes for laboratories a convenient generator of electricity, requiring but a lamp to keep it in action. Of larger dimensions, heated by coke, it generates electricity with a constancy and an abundance of supply never before realized.

HYDRAULIC MORTAR IN FRANCE.

From "The Architect."

The particulars, derived from official documents, of the manufacture of hydraulic mortars for the production of concrete intended to be used under water, as practised in the Government works in the north of France, have been published.

These mortars are generally composed of the hydraulic lime of Tournay, coal cinders, and Dutch strass, in powder. These substances yield a rich mortar, which rapidly acquires good power of resistance. The concrete, when mixed with small materials, is easily laid under water, has little waste, and forms excellent foundations.

The only inconvenience attributed to this kind of mortar is the complication of its manufacture which requires four perfectly distinct operations, demanding, if not special workmen, at least men of a certain amount of intelligence. These operations are:—(1.) The sifting of the lime in powder. (2.) The addition of the proper quantity of other materials. (3.) The mixing them together in the dry state and afterwards adding the proper quantity of water, and lastly, the mixing up of the mortar itself.

The work is carried on night and day, and, in one instance, employs in the twenty four hours 28 men and 6 horses; yet, with this considerable force, only 1½ tons of mortar per hour are produced, or 36 tons in the twenty-four hours, or about the quantity necessary for the formation of 72 cubic metres of concrete per day.

The Minister of Public Works has sent to the Vienna Exhibition the model of a machine, on scale of 0.10, which, with the aid of a steam motor, performs all the operations mentioned above. This consists consequently of four distinct parts, the bolter, distributor, dry mixer, and the crusher and maker. The bolter is mounted above the distributor, and is much like the ordinary flour-bolting machine. The lime, previously reduced to powder, is carried by two men in wooden boxes, each of which holds 22 gallons; it is emptied into the upper part of the bolter, and the lumps, etc., fall out at the opposite end into a truck. The bolter is composed of iron plate pierced with holes of rather more than a millimetre in diameter (rather less than $\frac{1}{20}$ of an English inch), and the sifted lime falls into a chamber perfectly tight, glazed traps allowing the interior to be seen, and, when necessary, visited. On a level with the floor of this chamber is the distributor, which is composed of three parts, each 4⅜ in. in height, but varying in size in proportion to the quantities of the several materials employed.

The vessel which measures the quantity of lime is placed under the chamber, and the other two parts beneath receptacles provided for the strass and cinders. The ca-

pacity of these three measures is for each nearly a metre. They are connected by their upper edges to the same supporting plank or table. Beneath these measures turns an iron disc about ¼ in. in thickness, connected with a vertical arbor. A large opening is made in this disc, so that at every revolution it alternately opens and closes the lower part of each of the measures. Beneath the first set of these is another of exactly the same form and capacity, and with the vertical arbor already mentioned is a second disc which closes the bottoms of the lower set of measures, the two sets being only separated by the thickness of the upper disc. The openings in the two discs are not coincident, so that when one of the upper measures is open, the lower corresponding one is always closed, and *vice versa*. The discs are set in motion by a spur-toothed wheel, and can be thrown out of gear at will. The action of the measures is self-evident. When one of the upper set is full the disc below it opens and allows the contents to fall into the corresponding receptacle below, and as the disc proceeds on its course, the lower measure is closed above and opened beneath, when its contents fall into the mixer. The disc makes 17 revolutions a minute, so that each of the three measures is filled and emptied as many times in the same period.

The mixer, which is placed beneath the distributor, consists of a fixed cast-iron cylinder, with an opening above at one end, and a horizontal arbor passing through it longitudinally, which makes 31 revolutions per minute, and which is furnished with palettes set at uniform distances around it, and at an angle of about 45 deg. to the axis. These palettes reach nearly to the circumference of the cylinder, and while mixing the ingredients, cause the whole to pass towards the further end of the cylinder. Towards the middle of the cylinder is a trap by means of which the progress within may be observed, and at the same point two jets of water are introduced from a cistern placed about 6 ft. above.

The mortar falls, perfectly mixed, from the cylinder to a mill beneath, which consists of 3 rollers of unequal diameter, all geared with each other. Looking only at the mortar as it issues from the mixing cylinder, the mill would appear to be completely superfluous, but it has been found that mortar made by mere mixing is of much less density than that which has passed through a mill of any kind afterwards; hence the addition of the latter to the machinery in question. The whole of the apparatus is simple, and easily taken to pieces and repaired, or the parts exchanged.

The engine used to drive the machinery is of 6-horse power; its axis makes 85 revolutions a minute, and drives, on one hand, the bolter, and, on the other, an arbor fixed on the frame of the machine itself, which communicates motion to the distributor by means of a driving band, and to the mixer and mill by means of gearing.

PROBABLE CAUSE OF THE DESTRUCTION OF BOILER TUBES.

By J. H. KIDDER, M. D., U S. Navy.

Written for Van Nostrand's Magazine.

It is a fact familiar to all practical engineers that the tubes of marine boilers, attached to condensing engines, whether they be supplied with fresh or salt water, "wear out" sooner or later, and have to be renewed. The term "wear" is, however, scarcely used with propriety in this connection, since when thus damaged boiler tubes do not present an appearance of uniform erosion, such as would result from "wear," but are riddled with holes and marked by pits or depressions. To the eye of a medical man these holes and pits bear a remarkable resemblance to ulcerations of the skin, the destruction of metal being greatest in the centre, and irregularly graduated thence toward the edges, so that each pit is of a funnel shape, its sloping sides presenting a *stratified* appearance, as if the rodent action had been irregular and intermittent. The holes and pits occur always upon that surface of the tubes which is immersed in the water contained in the boiler. So far as I am aware, the cause of this kind of destruction of boiler tubes has not yet been satisfactorily explained, although there is an opinion current among practical engineers that the presence of copper has something do with it.

By the kindness of Mr. W. C. Selden, of

this city, I was permitted to visit the steamer Clyde, of the Galveston line, on the 31st of July last, and to witness the operation of a filter which he had devised for the purpose of preventing this injury to boiler tubes, and which had up to that time proved successful. A long iron box, fitted with a steam-tight cover, was introduced between the condenser of the Clyde and her boilers. This box was divided into compartments by diaphragms of felting, pervious to water, and the compartments themselves filled with coke. By means of this simple contrivance Mr. Selden had collected a considerable quantity of a greasy, earthy substance, showing patches of a brilliant cantharidal green color, but generally of a brownish black. This substance he believed to be the real cause of the holes in boiler tubes above referred to, and, certainly, this being removed, the tubes of the Clyde had ceased to "wear out." At Hecker's flour mills also, when fresh water is used, the boiler tubes had required constant renewal, as in cases where salt water had been used, until the introduction of the filter, with the same beneficial result thereafter.

I had the opportunity of examining a portion of this substance, with the result hereinafter presented. The examination was necessarily incomplete, and can have no claim to chemical accuracy. Its results are presented in the hope of attracting the attention of practical chemists to what seems to be an important subject.

The specimen examined came from the condenser at Hecker's flour mills, and consisted of irregular, greasy lumps of mixed brown, black, and cantharidal green color.

(*a.*) A quantity of the mass was warmed, treated with alcohol (90 per cent.), and filtered, washing freely with alcohol. A green solution passed through the filter, becoming, on the addition of dilute sulphuric acid, reddish brown. On adding water, an oily stratum (oleic acid) rose to the surface of the liquid, somewhat disallowed by the sulphuric acid, which was too strong.

(*b.*) The residue on the felter was washed with ether, bringing down a little more greenish solution and some free oil. The substance remaining on the filter is dark brown, friable, and insoluble in water, alcohol, and ether. It is found to consist largely of carbon, with traces of iron, copper, and zinc.

(*c.*) A strong solution of chemically pure sulphate of copper was prepared and added to a filtered solution of pure oleate of potassa (prepared from olive oil and liquor potassa) in alcohol. The resulting oleate of copper was dissolved in hot alcohol and filtered; on evaporating to dryness, a green pulverulent mass resulted, which became tenacious and of darker color when heated.

(*d.*) In the same way an artificial oleate of iron was prepared for comparison; a thick, dirty, green mass, only partially soluble in alcohol.

(*e.*) A fresh portion of the green substance dissolved out of the original specimen by hot alcohol was heated to boiling, at first in alcohol, afterwards in water, immersing a clean knife blade in the mixture the while. A minute but quite perceptible trace of metallic copper was deposited upon the iron.

(*f.*) A small quantity of the alcoholic solution obtained by "*a*" and "*e*" from the original substance was decomposed by a small quantity of dilute sulphuric acid as in exp. "*a*." An oily stratum rose to the surface. Connecting the subnatant fluid with a two-cell Smee's battery, and immersing a clean iron spatula in connection with the negative pole, an instantaneous deposition of metallic copper upon the iron occurred.

(*g.*) Replaced "*f*" by a solution of pure oleate of copper, made artificially by "*c.*" Upon adding dilute sulphuric acid, a separation of oleic acid occurred as under "*f*," but in much less quantity, in proportion to the amount of oleate of copper used, than appeared by that experiment. On immersing the spatula in connection with the battery, as before, copper was plentifully deposited, scaling off from time to time, particularly over spots of rust, and floating free in the liquid. When the deposition of copper had become less active the liquid was tried by ferri-cyanide of potassium, indicating the presence of iron in large quantity, as protoxide. Since this last solution was made with only chemically pure sulphate of copper, olive oil, and liquor potassa, the presence of iron could only be accounted for by supposing an interchange between the copper of the solution and the iron of the spatula. By adding a small quantity of melted wax to "*f*," oleic acid was separated in a solid cake, and, as has been seen, metallic copper was obtained from the fluid portion by the aid of the galvanic current, the remaining solution showing the presence of iron, derived from the sputula, used as negative pole.

These experiments seem to have established the presence, in the substance collected by Mr. Selden's filter, of an oleate of copper containing a larger proportion of oleic acid than the artificially prepared salt (*vid.* "*g*"). By exp. "*e*" it would also appear that under the influence of heat and in presence of iron an interchange will occur between the metals, oleate of iron being formed and metallic copper set free, this interchange being much more rapid when the chemical action is intensified by galvanism. Besides oleate of copper the substance examined contains free oil, a large quantity of carbonaceous matter, and traces of copper, iron, and zinc. The experiments have been detailed, at the risk of tediousness, in order that any error that may have been committed may be more easily traced.

The presence of oleate of copper may be accounted for by the decomposition of the olive oil used in lubricating the piston into oleic acid and glycerine. Since a heat of between 400 deg. and 500 deg. Fahr. has been found in practice necessary to this decomposition (Watt's Dict'y Chemistry, Vol. II. p. 886), it is manifest that the steam from the boiler can never be hot enough for this purpose. But it is easy to believe that along the line of friction between the piston and sides of the cylinder an exceedingly high temperature is momentarily produced at each point of contact. The quantity of this heat of friction is trifling, but its intensity is very high, quite sufficient to decompose the thin film of oil interposed between the piston and the sides of the cylinder. In the process for the manufacture of glycerine by the injection of steam (Watt's, *loc. cit.*), it is found that glycerine is easily separated from oleic acid, owing to the fact that it is carried along much faster and farther by the escaping steam than is the latter. A small portion of oil, then, having become decomposed into oleic acid and glycerine, the latter passes through the condenser first and harmlessly, and the former somewhat later. In the condenser the brass tubes are exposed to the powerful comminuting impact of steam at a high temperature and pressure, and their substance is thus finely divided and placed under the most favorable circumstances for union with the free oleic acid which the steam brings with it. Oleate of copper is then formed (as I suppose) in the condenser, and appears as bright-green greasy masses, which are carried from the condenser into the boiler.

Here, being quite insoluble in water, these masses accumulate (in accordance with a familiar law) in those parts of the boiler which are least disturbed by currents; and it is precisely in those parts (at the ends of the tubes) that the most corrosion is found. Settling upon one of the iron boiler tubes a mass of oleate of copper adheres thereto, and, favored by the conditions of high temperature and pressure, the deposition of copper and absorption of iron begins. If the oleate of copper were soluble in the water of the boiler, the erosion of the tubes would be uniform over their entire surface. Being insoluble, however, its action is confined to the surface of contact, hence the small holes characteristic of this kind of injury. Since, as shown by exp. "*g*," copper thus deposited will remain adherent only to perfectly smooth iron, and since boiler tubes are never in this condition, the copper is probably removed by the action of water as fast as deposited, leaving constantly a fresh iron surface for further action. Whether the action which takes place in the boiler be galvanic or chemical is uncertain, if indeed there be any essential difference between these two modes of action, other than a difference of degree.

Mr. Selden has been in the habit of adding a quantity of free soda to the contents of his filter, having observed an acid reaction in the water which leaves the condenser. Since, however, the oleates of the metals, oleic acid, and free fat are alike insoluble in water, the advantage of this proceeding would seem to be at least questionable. For if free oil be present the soda added will form a soluble oleate (soap) which may pass through the filter, and is readily decomposable by any soluble metallic salt which it may meet, forming the very oleates which it is the object of the filter to exclude. If free oleic acid be present it is rendered soluble by the caustic alkalies, and its power for mischief thereby increased; while the metallic oleates, although not decomposable by soda, may, if acid salts (as seems probable by "*f*" & "*g*") give up to it a portion of their oleic acid which would otherwise be stopped by the filter. Moreover, since sea-water contains an abundance of calcic and magnesian salts, any free oil or oleic acid which might pass over into the boiler would be at once converted into an insoluble and harmless lime or magnesian soap in a marine boiler. And it is by no means certain that, even if not

so decomposed, they possess any hurtful power when uncombined with a metallic base. Lime is the only alkali which is theoretically likely to be of advantage, and that only when used in connection with a fresh-water boiler.

At Hecker's mills the condensed water after leaving the filter is treated with atmospheric air, forced through it from below. The resulting water is perfectly free from taste or odor and quite potable. It seems possible that the hitherto insuperable difficulties in the way of freeing condensed water on shipboard from a certain unpleasant empyreumatic odor and taste may be overcome by a similar treatment.

NAVAL LABORATORY,
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THE IRON-CLAD QUESTION.

Translated from Rivista Marittima (Italian), for the Junior Naval Association.

The question of the future of iron-clads is certainly a most complicated one; dread of allowing ourselves to be surpassed by other nations, and that of spending many millions upon ships of doubtful success, produce great uncertainty. In England, where the naval question is one of vital interest, where there are glorious traditions to continue and a supremacy to maintain, and where, especially, the country recognizes the importance of the navy, and is prepared to make serious sacrifices to keep it in the first rank,—in England, naturally, the question has been discussed at greater length and more advantageously than elsewhere; the press has studied it with some real acquaintance with the case, and its criticisms, though often unjust, have not been dictated by some fancy for casting reproaches at an important institution, with the sole object of creating opposition or of amusing the public, but were intended to throw light upon useful ideas, and to promote the introduction of additional improvements; so that to study the actual state of affairs, we can have no better guidance than that of the English journals of most authority on the subject, like the "Engineer" and "Engineering" and others, from which the following observations have been extracted, in great part word for word.

With the loss of the Captain practically ended one of the most important disputes which have ever arisen in maritime affairs; for many years the relative advantages and disadvantages of ships of low freeboard (*piccolo bersaglio*), like the Captain, and of those with higher sides, of which the Devastation is the type, had been discussed with ardor and ability. Men of authority were divided into two camps, and the discussion sometimes became so violent as almost to degenerate into personal attacks; scientific men of other countries took part in it; never had any subject been so generally considered as that of the construction of ships of war. In the end, the views of Captain Coles were painfully condemned by the catastrophe which crushed the defenders of the Monitor system. In the meantime, the fleet had been to a great extent re-constructed, and there was a truce to discussion, when a letter from Mr. Reed, published in the "Times," recalled the attention of the public, by awakening a general panic by means of certain obscure phrases, in which he seemed to allude to inventions doubly superior to his own constructions of two years before, and the consternation of the public was as great as though the English fleet had been sunk, or driven from the seas by the Russians or by the Extra-Europeans. Nor were there wanting anonymous writers, who asserted that Mr. Reed's ships could neither steam, nor sail, nor fight, not even float. Meanwhile, the attention of the public was directed anew to the affairs of the navy; new discussions were brought on; and there were not only two great camps, but even a dozen parties, all of which pretended to be able to give to the world the war ship of the future. In these controversies it is highly probable that considerations of real importance would be lost sight of, if an attempt be not made to guide opinion into a path advantageous to the nation. There is no better way of doing so than by making a brief investigation into the force of the navy, and by examining rapidly what progress may be hoped for in every class of vessel; and above all, it is well to consider, what are the requirements of the State, and to what extent they are met by the means at present in its posession. To England are necessary three great classes,

or types of ships:—The first is that of large vessels with heavy armor plating, charged with all the duties which formerly fell to the lot of the ships-of-the-line of from 70 to 120 guns; the second is that of swift, unplated ships, heavily armed, destined to maintain the police of the seas; whilst the third and last consists of ships which may properly be called floating fortresses, intended solely for the defence of the coasts, or rather of the ports. Let us begin with this last class, to which belong the circular iron-clads mentioned by Mr. Reed. Such ships should never go out of sight of land, or rather should but rarely go outside a harbor; they would not have to carry more than twenty-four hours' coal, that is a couple of hundred tons. It would not be difficult to make them invulnerable to the efforts of the most formidable guns which will ever be brought against them, and not having to bear a heavy weight of equipment—coal, water, and provisions—they might carry plating of 24 in., and two or even four guns of the heaviest calibre. Their work would be limited to the destruction of an enemy's fleet which might dare to approach the great seaports; they would be, as it were, house-dogs; they would not require great speed, because it would not be their duty to pursue the enemy. No naval architect would find any difficulty in the construction of similar ships; for, although he would have to make them large enough to carry armor-plating and guns, he would not have to think of coal, stores, powerful machinery, rolling, or any of those things which are the despair of the constructor.

The construction of swift unarmored ships is not by any means a difficult problem: the coal would take the place of the armor-plating; and though serious consideration of their stability and power of keeping the sea for long periods would be necessary, still these are difficulties which it may be asserted can be surmounted successfully. There are not wanting opponents, who declare that these swift unarmored ships would be useless because they might be easily destroyed by iron-clads; but even then their case would only be that of the frigates in the days of the line-of-battle ships; the former were able to avoid their more powerful antagonists, and were useful and popular ships, so the modern unarmored frigates or corvettes would fight with each other and leave the iron-clads alone; whilst these latter would find a by no means agreeable opponent in a ship running 17 knots, and carrying a couple of 25-ton guns, and would have to burn a good deal of powder to keep her at a distance. It may therefore be held to be necessary to have a good number of these light vessels, good under sail and especially so under steam, to protect the national commerce and destroy that of the enemy.

It now remains to consider the class of heavy iron-clads which would form the fleet-of-the-line; but here we encounter many difficulties. First of all, it must be admitted that these iron-clads are the true strength of the naval power of the country; they are what were the huge liners of Nelson, and in them fighting qualities should have precedence over all others. It was not, assuredly, the swift frigates, nor the saucy corvettes, that achieved the maritime supremacy of England; a lighter fleet might leave astern these heavy vessels, but it would end in destruction under their fire. As it then was, so will it be hereafter: the ships that can best maintain the line of battle, and, by keeping together, best resist the most formidable assaults, will be master of the sea, and a greater speed or better qualities as cruisers will not, in the long run, serve its adversaries. Now, as then, the true strength of the English fleet is in the heavy ships-of-the-line; to them belongs the duty of guarding the coast from the attacks of any hostile fleet whatsoever, and of pursuing it, if need be, wherever it can go to reduce it to extremities; they ought, moreover, to be fit for distant service and able to proceed to the South Atlantic, to India, to the Pacific, wherever indeed great actions may be fought, resting on a local base of operations. This established, let us see what should be the qualities of such ships. It being probable that in future naval actions, as in those of former days, ships will encounter each other at close quarters, and that a ship will often have to sustain a concentrated fire, un-sinkableness (*insomergibilita*), or the possibility of resisting shocks of all kinds, obtained either by means of armor-plating, or in other ways, becomes a condition of the first importance. And when also, as is possible, the beak or the torpedo may supersede the gun, the ideal ship-of-the-line should always retain the same defensive power, so as to be able to use in action all the means of offence with which it is supplied, in spite of the

enemy's guns, which will certainly reserve themselves to keep, if possible, at a distance both rams and torpedoes; so that not only will the thickest plating be always necessary, but also and even yet the most powerful guns, though but of secondary importance. To speed is assigned less importance because it will be necessary to sacrifice to it some fighting qualities, though one or two particularly fast ships-of-the-line, like the Fury, may prove most useful, if it is always safe to approach an enemy short of coal, or in a position which cannot be avoided; and at the moment of action the fastest engines will go slower, since passing with great rapidity close to the enemy cannot lead to important results. Great importance, however, will be given to facility of manœuvring and to the powers of the ship as a ram, since it is probable that on the ram will depend half, if not the whole result of a naval action. With respect to locomotion, English ships-of-the-line will always have to be so fitted as to go wherever Nelson went, relying upon their engines only, allowance being made for facilities of replenishing their fuel and of the most rapid actual means of communication, which would certainly in future render a pursuit much shorter than that in which Nelson chased Villeneuve.

For the defence and maintenance of order in the colonies, ships without masts may be always made use of, or those furnished temporarily with a jury rig, it being always possible to have a local supply of coal. So that for ships-of-the-line, masts could be entirely abolished, it being acknowledged that their absence is an important element in their fighting qualities. There are not wanting, however, opponents of this aboli tion of masts, and not long ago a writer in the "Daily News" took advantage of the fact of an accident having happened to a supplementary portion of the Devastation's machinery during her trial, to draw a lamentable picture of that huge monster helplessly abandoned on the sea, and waiting for a friendly tug; but trial trips serve especially to point out the defects of the machinery; and in reality, at the present day, both engines and boilers—except in fatal cases—exhibit sufficient guarantees to trust to them alone for the working of the vessel. As to sea-going qualities, the ships-of-the-line should be able to keep the sea in any weather; but that need not include the necessity of being able to steam swiftly against a heavy sea, particularly when it is thought proper to adopt low extremities for the devolopment of the turret system, for a ship can be a good sea-boat without this superfluous quality.

Having laid down these conditions, the English journals inquire how far their fleet complies with them. This fleet is composed of the Devastation and Thunderer already launched, and of the Fury as yet unfinished; all are of the same type except that the Fury has greater defensive powers and is faster: she promises to be one of the swiftest ships of war in existence, and thus will be exempt from any difficulty that may arise from accepting slowness as an essential characteristic of line-of-battle ships. But it is only by comparison that the Devastation can be regarded as slow; at the measured mile she ultimately attained a speed of about 13.9 knots, a most excellent result if the relation between the nominal power and her displacement and the fulness of her lines be taken into account. As to facility of manœuvring and proceeding under steam—from long use—the new designs appear perfect; the cruise of Nelson to the West Indies and back is quite within the power of these ships, even without replenishing their coal supply. As to their floating qualities and armament they are quite up to the level of the times, being therein superior to any ships yet launched, and only threatened with a rival of doubtful superiority (at best but equal to the Fury), the Rusian ship Peter the Great—still on the stocks. The sea-going qualities of the ship remain for consideration, but upon them nothing positive can be said before the final trials; still, the trials made up to this time, of the Devastation, promise, even in this respect, very satisfactory results.

To this powerful group of three ships must be added the two rams, Rupert and Hostpur, which will of a surety prove useful auxiliaries in a general action: both are protected at the water-line by a plated belt 11 in. in thickness, which is extended only 18 in. above water, at which height there is a deck protected by thick plating, capable of resisting plunging fire from powerful guns; the sides rise above the deck un-armored, but within there is an armor-plated casemate (*ridotto*).

In the Hotspur, a ship of 2,600 tons, the casemate is elevated above the upper deck and forms a fixed turret with several parts, in which there is a 25-ton gun mounted on

a platform, protected by armor of only 8 in. In the Rupert, which is of 3,160 tons, the casemate carries armor of 12 in., and terminates in a revolving turret, plated like that of the Devastation and armed with two 18-ton guns. So that these ships are not unworthy of being placed in the line of battle with the Devastation, but the power of their artillery, especially that of the Hostpur, is small, since they are protected by weak plating, which, however, is of minor importance as they are specially designed for ramming. They are not intended to keep the sea for long periods, for they have only the usual supply of fuel. The speed of the Rupert is 14 knots; that of the Hostpur is between 12 and 13, and will probably be adopted in naval operations near the home coasts. Besides these five ships, the Glatton may well take part in a battle fought in home waters, her armor being as thick as that of the Devastation, although she has but one turret and two 25-ton guns instead of four of 35-tons; her speed is 12 knots and her coal supply moderate. But even excluding the Hostpur and Glatton, the Thunderer, the Devastation, the Fury, and the Rupert, constitute a fleet of extraordinary individual power (though small in number), fit to go wherever the best ship of the line may be required. It is natural that there should be a desire to have, beyond everything, this number increased, in view of what other powers may do or are beginning to do; but the fleet at present existing, small though it be, is not at present in danger of being surpassed. Before making fresh constructions it is necessary to make careful trials at sea with the Devastation and the Thunderer, and to study well in what way the powers of guns and armor may be still increased, without exceeding the moderate dimensions of present ships. Mr. Reed and other eminent persons (amongst them Admiral Sir Spencer Robinson) cry out against the Government, which they accuse of having hesitated in the path of progress; but even though England should not construct another ship for two years she would still remain at the head of naval powers; these two years in advance, which compensate for the immense sums spent on the navy, authorize the nation to rest in its course to take breath whilst other powers still crowd sail to catch up with, or surpass it. Mr. Reed asserts that his best designs are already antiquated; but what kind of ships then should be constructed? To this question there is no answer. With the increase in the thickness of armor the dimensions and the cost of the ship of necessity increase. As for armor, the maximum has, perhaps, been already reached, and there exist guns capable of penetrating the Devastation at a greater distance than 1,000 yards. Ships designed for the defence of ports may be protected by armor almost *ad libitum*; but it is not the case with ships destined to go to sea. It is difficult to imagine a ship that can carry more than a long strip of plating capable of resisting 35-ton guns; and the limits of artillery have not yet been reached.

There, therefore, arises a doubt as to whether or no armor of 12 in., which can be pierced, is worthy of the sacrifices that must be made, in order to have ships capable of carrying it; but if it be preferable to have no armor, rather than to have it of but 6 or 7 in., which can easily be penetrated by projectiles, the same cannot be asserted of a thickness of 12 in. Moreover, there are but few guns afloat which can penetrate it; and when we take into consideration the remark of Captain Osborn, published in the "Times," that that which is most to be dreaded in battle, is the bursting of a shell between decks; if armor is strong enough to sensibly retard passage of a shell, the force of the explosion will be backwards, and although the head of the projectile may have penetrated, the damage done by splinters would be nothing in comparison to that which a projectile would make after having completely penetrated the plating. From this it would result that even against the most powerful guns, armor of 12 in. will render good service, as also slighter armor would against light guns. The theory of Captain Osborn points to other ideas upon the employment of armor; if the heaviest explosion of the projectile takes place from without and but the pieces enter, a lighter internal protection will suffice to ward off all danger. After all, we should consider the necessity of carefully experimenting to discover if two plates, distant 5 or 6 ft. apart, the outer one 7 in. thick and the inner of 5, would not give better results than a single plate of 12 in.; the first would break the projectile and the second would resist the pieces, no filling being interposed between the plates to allow full liberty to the dispersion of the explosive effect.

In one way or another, it is probable that it will become necessary to increase still more the thickness of armor plates, and that it will be necessary to advance boldly to a thickness of 10 or 20 in., but that will necessitate a diminution of the surface plated; something besides may be obtained by the abolition of the turrets, according to an idea expressed hereafter; if the length of the casemate can be reduced, it will perhaps be necessary, in addition, to abolish the armored belt outside the casemate, carefully protecting by means of the cellular system, the neighborhood of the water line; to reduce the dimensions of the upper works, to widen somewhat the casemate, to have the necessary means of locomotion, to obtain a satisfactory stability, it will be necessary to still more diminish the length and increase the width of ships. It being necessary to make these sacrifices, in order to have thicker armor, it is certain that the voice of those who propose its abolition will make itself heard more than ever; still it cannot yet be doubted that armor is a necessary evil.

The means of offence, except with regard to the active use of torpedoes, appear at present stationary; every ship is by nature a ram; guns may be produced up to a weight of 50 tons, but will probably be mounted in the same way; the use of powerful artillery is more important than ever; an arc of fire perfectly free, except as regards the intervention of the masts, has been obtained; also the details of the turrets appear completely satisfactory. However, it is possible that the necessity of reducing the surface to be plated, may lead to the substitution for turrets of Moncrieff's system, which allows the gun to be lowered beneath the shelter of the deck after every round. Offensive torpedoes, without doubt, offer an unlimited field to invention, but their employment does not seem to greatly modify the type of ships; to work them the enemy must be approached, and that naturally implies the necessity of stout plating to resist his guns, and good artillery to engage him. The small "torpedo ships," swift and unarmored, may be of use for a nocturnal surprise, which might be better carried out by a steam launch, or boat with oars; but it would be prudent for her in the ocean, in the light of day, to keep at a distance from the Devastation. A ship like the Devastation wants but a few simple additions to her prow, under water, to become the best type of "torpedo vessel;" Harvey's towing torpedoes and the use of booms for outrigger torpedoes—a powerful method of offence, too little appreciated on this side of the Atlantic—can be made use of quite as easily by the Devastation as by her diminutive and swift, but unarmored opponent. But these important improvements would not induce radical modifications in the construction of ships; torpedo appliances would, of course, be simply accessories; and even though the Moncrieff system be substituted for that of the turret, a ship like the Devastation could easily be altered; a low turning platform, the machinery for raising the gun, and a protection against water penetrating below, might be arranged without much difficulty; the gun would be a little less protected, and a weight of more than 100 tons would be saved; but turrets or no, it is probable that the central casemate will remain unaltered.

Also, the improvements in the motive power should be carefully studied; speed has become more than ever important from the serious dangers of the ram and the torpedo; and the engines of ships of war should answer as fully as possible to these three requisites:—1. Great power and reasonable economy at any speed. 2. The greatest security against the accidents that in time of action may render them temporarily unserviceable. 3. Facility of repair and power of isolating unserviceable parts.

To obtain these results it is essential to reduce the size of the engines, and especially of the boilers, and therefore to use only engines of a high pressure, which Mr. Reed recommends to be of at least 60 lbs.; he also recommends for iron-clads, the introduction of oval boilers, which, in spite of the inconveniences of cylindrical furnaces, admit of the most perfect utilization of the depth of hold; for un-armored ships he proposes to employ boilers made entirely of tubes, these being less liable than others to damage from shot; and with all engines, with a view to obtain the most perfect combustion possible, he recommends the use of ventilators to give a supply of air to the furnaces. Mr. Reed says that compound engines only produce economy of fuel by raising the pressure to double that of simple engines of twice the power; and he believes, that even with the latter, by increasing the pressure, almost equal results may be obtained, whilst there will be avoided the

accidents so easily caused in action to compound engines on account of all the accessory gearing necessitated by the various dimensions of the cylinders and by their mutual dependence. With regard to weight, there will be no great difference between the engines of either type designed to work up to a pressure of 60 lbs., with the same capacity of expansion. Considering the position of the engine with respect to the hull, Mr. Reed is of opinion that, the dangers to be feared from rams and torpedoes being beneath the water line, the protection of engines placed low down is no longer such as to make up for the inconveniences springing from such a position,—as for instance, that of interfering with the water-tight compartments of the vital parts of the ship; when the protection of the armor allows it, vertical or oblique, engines may be used with advantage, and may thus be better distributed within these same compartments. The sub-division of the machinery will perhaps allow of its better protection, and may render less disastrous the consequences of an accident to any part of it. Mr. Reed would prefer to adopt exclusively double screws, and to divide the cylinder capacity between two pairs of simple expansive engines, also to give up to some extent economy of fuel; thus there would be two compartments of reasonable size instead of one very large one; one being at the extremities for the boilers and the other between the foremost and after boiler compartments; in this way may in general be used one pair of engines after the other has been rendered unserviceable.

These considerations may give rise to great changes in the internal arrangements of ships.

As to sea-going qualities, nothing certain can be asserted before the trial of the Devastation; then will be ascertained the result of having a prow of moderate height. To give accommodation to the ship's company, the armored deck has been lowered almost to the level of the water, throughout a distance of 50 ft. from the stern; the sides of the forecastle are 9 ft. high, and abaft they are between 11 and 12 ft. In the Fury, however, it has been judiciously determined to keep the whole of the armored deck at a height of 4 ft. above the water, otherwise it would be necessary to raise the level of the superstructures to that of the central part—which would prevent a depressed bow fire—or to give up those places as quarters for the crew for want of space. This is the opinion of Mr. Barnaby, who proposes a side of only 4 ft., with a flying bridge strengthened by girders, carried forward at the height of the present forecastle, for working the anchors.

Thus the low extremities will be well proved, and should the results be unfavorable, it will be sufficient to include the space under the flying deck, and try the 9-ft. sides afresh; but it is likely that this plan will not be carried out, and that the Fury will have in the bows a low forecastle above the armored deck, and abaft a side of 9 ft., according to the first plan. If the bows of these vessels should turn out to be too low, they may be raised 2 ft., or movable bulwarks may be added to the fore part, of sufficient strength to resist the sea. It seems, however, probable that the height given to the bows will be found sufficient, and that its volume will be found adequate to raise them above the breaking of the waves. It does not appear that any change has to be made in the sides amidships, already between 11 and 12 ft.; but the very low stern will not perhaps be equally approved of in practice, from its having a tendency to swamp the ship; the reason for making it as it is has passed away with the old superstition of a low freeboard. In existing ships, the stern may easily be carried to the same height as the bow, and thus will disappear the objection that the fore part would be exposed to a stern fire from a ship of greater power than the Devastation, or the Thunderer. In the Fury this inconvenience does not exist, because the breastwork occupies the whole width of the ship as an ordinary central battery with rounded ends. This change would probably be continued because it places all the berthing of the crew under shelter; berthing outside the armor, well lighted and well ventilated, will undoubtedly be preferable, and its destruction in action would not be important; but if the low bows, useful to allow of depressed fire, give good results, no other construction should be retained above water but the breastwork itself.

From these considerations it results, that for England, already protected by a most powerful fleet, it will not be prudent to begin at once construction of a new kind in the present uncertain condition of affairs; since her wisest policy is to halt for a short time, if she be always in time to equal any-

thing good that may be launched in foreign dockyards; and the writer in the "Engineer" justly concludes, by recognizing the necessity of building other ships, but observing, that whilst it would be a grave error to construct at once ships similar to the Devastation, it would be a far more serious mistake to seek for designs before having tried her.

It is fitting, then, that Italy should profit by the experience of others, and proceed with the greatest caution to utilize as far as possible the few naval means at her disposal, because with us, as with other people, the preventive solution of the problem acquires a great importance. As has been well observed, it is not enough to build ships that may be worthy of comparison with those of other nations; but it is requisite for these ships to answer as completely as possible to the special interests of the country.

To the national navy has clearly been intrusted the defence of our extensive coast-line, and of the merchant vessels taking refuge in time of war in our ports. The fortresses on shore are certainly not adequate to the fulfilment of this object; to insure conviction, it is but necessary to glance at the map of Italy, and to consider for a moment what a vast number of fortresses would be required to protect the points at which a landing might take place, or even those places only which it would be specially desirable to preserve from the destructive effects of an enemy's fire.

Both fortifications and torpedoes will be of great utility, but they will be brought into practical use in but a few places, which the enemy will generally avoid; and what other protection can be given to the remaining portion of our coast, not sufficiently favored to be chosen as principal points for defence, but that of a squadron of ships? This possesses an immense importance, because it answers most completely to the duties imposed upon, and to the politico-military objects of, the navy. We have no colonies to protect; therefore in time of war the proper post of the fleet will be close to the shores of our country, which it has to defend; it need have no aggressive aims, but to be such as to cause every other navy to respect the integrity of the country, protecting the whole coast-line from the dangers of a bombardment and the perils of a hostile landing.

It is not, indeed, an easy question to decide which ships best answer to these requirements. At first the very natural idea presents itself to divide the iron-clad squadron into an offensive and defensive one—into ships, that is to say, destined to fight at a distance, and into others exclusively adapted to the defence of ports and roadsteads, and to inquire if such a division would, in its practical results, be really advantageous. What qualities should be expected in good ships of the squadron of defence? Great thickness of armor to secure the invulnerability of their own artillery, and the most powerful guns to inspire them with respect. As to motive power, although great speed would not be a necessary characteristic, still ramming attacks and offensive torpedoes, which will be much to be feared in future combats, demand that they should have good engines and that they should manœuvre with ease. But, with these characteristics, ships for defence would differ as little from those of offence as seems convenient, so that to divide the naval force into two distinct classes to adopt a single type for ships, which may, when occasion requires, act all together, is to insure success in cases of both attack and defence, or rather of passive and *active* defence.

To the special defence of certain points it will always be necessary to allot those iron-clads which the rapid progress of naval construction has left behind, and which, though inferior in fighting power to more recent ones, may prove of great assistance when supported by works on shore, or favored by the peculiar formation of the coast.

A doubt, then, arises if this continual progress will not render almost insufficient those ships which we propose to construct at present, but it seems probable that the practical limit will be reached by the projected designs, since there is a limit to the power of naval instruments of war, for it is not within the reach of human ability to pile up, in accordance with the conceptions of the imagination, great masses of iron on the ocean and manœuvre them with rapidity. It is therefore probable that, beyond the dimensions of the proposed plates, the studies of constructors will return rather to simplifying than increasing the means of defence; and then our present ships will not err by being too powerful and strong, a slight defect, for the special object of defensive operations.

Leaving out of sight the question whether or no a single type ought to be adopted for the construction of the new iron-clads, it remains to consider the proper qualifications. From the consideration that the principal aim of our fleet is not the destruction of that of an enemy, nor the possibility of fighting in distant waters, it would appear that we should not desire marine monsters, such as have composed the most recent squadrons; but that what is wanted is to have ships endowed with such powers of defence as to be able to withstand a hostile squadron in the event of military operations on our coasts, to hinder by its presence an enemy from attempting any important landing, and risking in our water that collection of transports which would be necesary to such an undertaking; and endowed with offensive powers to withstand effectually the enemy's guns, whenever he should attempt a cannonade. Moreover, although our squadron will not require immense supplies of fuel for long voyages, still its depots shou'd be considerable, to supply the most powerful engines and to keep them in working order, for so long at least as the steamers of the higher class lines of packets which would be made use of for the enemy as transports in case of a landing.

The attainment of these requisites, so necessary to the security of the country, is beset by such complications that we must raise the ships, truly *floating fortresses*, to enormous, or, at least, to very great dimensions. It is better to utilize economy of fuel and of other stores so as to increase the power of the guns, as well as to decrease dimensions, in order to place these warlike engines well forward on the path of naval progress. In addition to the characteristics just mentioned, be it noted that with large ships we can have at sea a greater number of guns at less expense than we could have them with small vessels. The weight of a two-gun turret is naturally less than than that of two with one gun each, and the cost of a ship with two turrets is less than that of two ships with one turret of equal power. Considering the qualities of a ship as a ram, with the necessary strengthening to avoid the fatal consequences of a shock, and the facility of applying them to defence against torpedoes and the appliances to be taken advantage of as means of offence, better results will be obtained with ships of large size than with others.

There will not be wanting many to maintain, with the most excellent arguments, that the sums required for the construction of these iron-clads would be better employed in that of small swift vessels, without armor, carrying a single heavy gun, a kind of floating gun carriages, and it cannot be denied that such may turn out most useful in action, if they are ably and boldly handled and favored by fortune; but in accordance with the strict logic of the argument, they would have to succumb, in spite of their superiority in number, to the blows of an almost invulnerable enemy, and with a view to an important interest such as the defence of the coast, we cannot trust to accident nor voluntarily give up any chance of success. Beyond all, it is necessary to observe that these floating gun carriages, armed with a powerful gun and of great speed, can exist only in the imagination of their proposers, so insurmountable are the difficulties in the way of their construction with the characteristics required in them.

To be complete, our fleet must be composed, besides the above-mentioned class of line-of-battle-ships, of a class of secondary importance, intended for the protection of our commerce and for expeditions, rather maritime than war-like, in distant waters. Such a class would not have to be very large, since in time of war our merchant ships, not having free exit from the Mediterranean, would probably be shut up in our own or neutral ports. Such a class ought to be composed of cruisers, swift unarmored ships, carrying powerful guns, destined in time of peace for distant expeditions—being with that object provided with suitable spars and rig—and in time of war, to watch the movements of the enemy's squadron, especially cruising in the neighborhood of our coasts, their artillery would perhaps suffice to keep at a respectful distance an isolated vessel, and their speed would enable them to avoid unfavorable encounters and to chase merchant ships belonging to the enemy, at least when not prevented by principles of international law.

These few remarks have been offered with the intention of pointing to the development which the country imperiously demands for its navy; or rather it has been sought to attract to their argument the attention of intelligent men.

The defence of its coasts is one of those

duties in which a nation, with respect to others, must not fail, and the equitable counter-balance of advantages which nature has bestowed upon the country, by circling it about with the sea, opens to it, in the rich paths of commerce, a life that inland people may envy. Italy will not be slow in reaching that commercial development which awaits her; our flag begins to show itself less rarely in the waters of the extreme East, many ships are constructed upon our shores, and this commercial progress will increase even still more when once it shall feel itself better protected.

It is necessary to recollect that to overlook the defence of our country's shores may one day perhaps be the cause of irreparable losses, and that prudence and duty counsel us to consider minutely every requisite for its persevering fulfilment. The question of our fighting fleet has been considered with the greatest attention, so that we may not have hereafter to bewail the consequences of over-confidence, of a too rigid economy, or even of the too great levity of former years.

Ships of war must be our fortresses for hundreds of miles from the margin of the sea, and in time of need; and repentant regrets will not suffice to protect our immense coast line, nor the numerous building slips, the merchant ships, the vast and wealthy cities so exposed to the attacks of a hostile fleet.

TESTS OF STEEL.*

By A. L. HOLLEY.

From the "Iron Age."

The intention of this paper is not to discuss this important subject in all its bearings, but merely to point out why mechanical tests of steel, as ordinarily made, are not, alone, of any special value to engineers—certainly not to general mechanical engineers.

The agents of the Barrow Hematite Steel Company, one of the largest and most successful Bessemer establishments in England, have recently distributed a report made by Sir William Fairbairn, on the transverse, tensile, and compressive resistances of certain bars of this steel. The number of tests is very large; they seem to be careful and minute; and the modulus of elasticity, the work up to the limit of elasticity, and the limit of working strength, are fully tabulated according to the latest formulæ.

This is very well—indeed, it is indispensable, as far as it goes; but it goes no further than to inform the ordinary engineer that there is an unknown substance which possesses these physical properties. As to what the substance is, the report gives him no working knowledge, for not a single analysis is given of any of the bars tested. The most that is said of some of them is that they are either "hard" or "soft," which is sufficiently evident from the experiments. "A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk." To the engineer who wants steel for a specific purpose, it gives only the faintest clue, to say that steel is hard or soft. There are a dozen grades of both hard and soft steel, adapted to different purposes. Rail steel is soft, and boiler plate steel is soft, as compared with many structural steels, and with the whole range of spring and tool steels; but the one perfectly adapted to rails would be useless for boilers.

In order that engineers may know what to specify, and that manufacturers may know not only what to make, but how to compound and temper it, the leading ingredients of each grade of steel must be known. Pure iron would be unfit for nearly all structural purposes. Upon the substances associated with it depend its hardness, malleability, stiffness, toughness, elasticity, tempering qualities, and adaptations to various structural uses. These ingredients are, indeed, impurities, but the term "impurity" unfortunately implies a defect, whereas the thing may really impart the essential quality. All the usual ingredients give what is called "body" to steel. Carbon, within specific limits, as is well known, gives hardness, elasticity, resistance to statical strains, and tempering qualities. Under

*Read before the American Institute of Mining Engineers, t Easton, Pa., Oct. 22 1873.

certain conditions of composition it even gives resistance to sudden strains. Manganese (and this fact, by the way, is not so generally known) gives, in different proportions, hardness, toughness, malleability and elasticity. Chromium imparts similar qualities, but to what precise extent we do not know, in default of a proper comparison of chemical and mechanical tests. Silicon, although considered a bane by steel makers generally, and, singularly enough, advertised as the great panacea for the weaknesses of steel by certain modern inventors, has probably, in proper proportions, a healthful influence on the physical properties of steel. Even phosphorus, the arch enemy of the Bessemer and open hearth manufacture, may, in some degree, be a valuable ingredient.

Whether or not certain foreign substances, which, separately added, produce similar results, would produce a better result if combined in certain proportions—for instance, whether carbon alone in any degree, or silicon alone in any degree, would make as good a steel for certain uses as carbon and silicon combined, it is, in default of proper experiments, impossible to state. The probability is, that there is a proportion of carbon and manganese which would give the highest possible value to all structural steels. We formerly added spiegeleisen to decarburized Bessemer metal solely to impart manganese to the oxygen of the oxide of iron formed in the Bessemer process.

We now add a larger proportion of spiegeleisen, not only to remove the oxygen, but also to mix manganese with ths steel. And we think we find that if the proportions of silicon and phosphorus are sufficiently low, and carbon does not exceed a third of one per cent., manganese to the amount of three-quarters of one per cent. gives the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails which no proportion of either carbon or manganese, not associated, can impart.

When we consider that two or three tenths of one per cent., and, in some cases, a fraction of a tenth of one per cent. of foreign metals, will change the character of steel in a high degree, and when we farther consider that the physical results of these combinations have never been tested or analyzed in any thorough and comprehensive manner, we may well reiterate the common expression, that the iron and steel manufacture is in its infancy.

But it is not necessarily in its infancy. We simply do not develop it. The general complaint of engineers and machinists is, that they occasionally get, but can never get regularly, the precise quality of steel they require; and yet it is probable that thousands of tons of steel have been made which are suitable for each of these purposes, but have been used for others, and that the precise grade required in every case could be reproduced by the 10,000 tons. The trouble is that neither the user nor the makers know what the material is. They have put no mark on it by which they can recognize it; they have kept no recipe. All they can do is to use ingredients of the same name, and approximately the same quality, and to guess at the physical properties of the product, aided by such crude tests as can be made during manufacture. Mr. Wm. H. Barlow, in a late address on modern steel before the British Association, says that one reason why steel is not more used for structural purposes is, that the metal is of various qualities, "and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality." But neither Mr. Barlow, nor any of his associates in Government experiments, proposes the true solution of the difficulty. It is no more necessary to test one or two of each lot of bars to destruction, in order to find out the quality of the rest, than it is to burn up a Chinese village to get roast pig.

If the user would *analyze* not one, but twenty samples of the steel that meets a particular want, and then base his order on an analysis that should come within the highest and lowest limits of the samples, he would get substantially the same metal every time. The problem is a more difficult one for the steel maker, since he must analyze the many materials that go into his product; but if he imposes the same restrictions on the makers of these materials —in short, if from the ore and limestone and coal, up to the finished bar, each user buys by analysis, and pays in proportion to uniformity, the production of steel of the most multiform grades and qualities, each homogeneous and uniform to any extent of production, becomes a possible, if not a comparatively easy, matter.

What are Sir William Fairbairn, and Mr. Barlow, and Mr. Kirkaldy, and the other

great experimenters in the physical properties of steel—in its adaptation to certain specific uses—what are they doing to relieve the engineering from these uncertainties? They are simply discovering the vast number of qualities which steel may be made to possess, without giving more than a clue to the method by which these qualities may be predetermined and reproduced. They are going to a vast expense of time and material to inform us, not that a certain combination of metals, but that a *bar of steel*, has such resistance and elasticity. This sort of experimenting has much the same value as the steam engine tests of a late chief engineer in the navy, of whom it is said that in a coal consumption test he would calculate the ashes to ten places of decimals, and guess at the coal put into the furnaces.

Moreover, Sir William Fairbairn may be doing injustice to other steel makers, to Brown, Cammell, and Bessemer—bars of whose steel he has also similarly tested, and found not quite so good for certain purposes as the Barrow bars are. But he neglects to make it clear that the disparaged bars may be better than these particular Barrow bars for other purposes. He makes the mistake, which we should suppose Sir William, of all men, would, not make, of being absurdly general and random in one element of his conclusions, while he is fractionally accurate in others—of cramming the whole matter of chemical ingredients into the terms "hard" and "soft."

The first and easiest step in the desired direction is to find out what *X* is. It is not necessarily a bar of steel made by Turton & Sons, which one tool maker will swear by and another swear at; nor is it necessarily a boiler plate steel which Park Bros. made once, and Firth got at twice, and Singer, Nimick & Co. hit two or three times. It is a steel which Turton, and Firth, and Park, and Singer can, either of them make by the 10,000 tons, if you will only tell them what it is made of, as well as what its physical qualities are. In the various uses to which engineers have applied steel, there are a vast number of specimens which have long fulfilled all the requirements. When more steel of the same sort is wanted, the usual method is either to apply to the same maker, who kept no complete record, and does not know what is wanted; or to get bids based on a stereotyped and very inadequate physical test, for instance, that the bar must stand such and such a blow from a drop. The lot of steel is made, and is, as well it may be, very heterogeneous in physical character, although it may be in accordance with the one test. The result is, that, under wear, some of it fails, or, under load, an excessive margin of safety must be allowed. The obviously rational way to reproduce a lot of steel which is proved suitable for any purpose, is to analyze many samples of it—at least for carbon, manganese, silicon, phosphorus, and any element which exceeds $\frac{1}{10}$ of 1 per cent., and thus to give the steel maker a recipe for making it.

It may be suggested that this chemical synthesis of steel will be ruinously costly. For certain exact purposes, such as the members of a long span bridge; or, for certain fine purposes, such as gun barrels, the cost of analysis, or any loss in applying to other uses the lots of steel that were not up to the mark, would be very small compared with the extraordinary margin of strength that must be given to an uncertain metal, and compared with the cost of occasional failures under final test. And this cost, whatever it is, the user, that is to say, the public, should and must bear.

But steel makers will find that working by analysis is not so very formidable, after all. The color test of carbon is already applied to all charges of all Bessemer and open hearth makers, and it is one of the most important. There is another view of the case: After a certain experience in comparing mechanical tests, which are comparatively easily made, with the more costly determinations of manganese, phosphorus, etc., the expert will not need to analyze every charge. He will learn to read manganese, approximately, in an elastic limit test, just as the expert blacksmith can now read carbon quite accurately by the water-hardening test. Herein will lie one of the values of the combined mechanical and chemical tests—that they will supplement and prove each other.

When the proper amounts of carbon, manganese, silicon, etc., for certain uses are known, it will not be impossible to approximate to them, in the Bessemer process, to a very helpful degree, and in the open hearth and crucible process, to a reasonably accurate degree. Of course, the character of the ingredients must be much more definitely known than at present, and numerous batches of nominally the same ingre-

dients, such as pig iron, blooms, or puddle balls, must be mixed, so as to largely dilute any high degree of impurity which any one batch may contain.

The thing first in order is, of course, to ascertain the mechanical properties of all grades of steel—not merely the individual resistances to destructive strains, which are but the stones that compose the mosaic, but the resistance within the elastic limit, which is the finished picture. To this end experiments like those of Sir William Fairbairn are indispensable, but to these must be added analysis of every grade of steel that can be produced, or the character of the metal is but half known.

In the present state of constructive and metallurgical art, it thus seems not only vitally important, but highly feasible, to increase in a large degree the uniformity of all grades of steel, and to make grades adapted to all special uses, instead of following the hit-or-miss and large-margin system, or want of system, that now obtains. Of course the change must come slowly, and its early stages will be attended with difficulty and expense; but there can be no question as to its ultimate success and its immense advantage in constructive and manufacturing engineering and art.

What probable expense of experimenting is to be considered when it will increase, possibly double, the resistance of metals to specific stresses, and decrease the present enormous margin of safety? It seems unaccountable that Government commissioners have so long neglected the chemical half of the problem—have so long neglected to complete the circuit, so that the metal will tell us its own story.

DERAILMENT.

From "The Engineer."

We have given in another place a short summary of twelve months' accidents in this country and the United States. We shall not reproduce any of the figures here, but we commend the statistics to the attention of our readers. It will be seen that the railway system of the North American continent, notwithstanding its imperfections, is worked somewhat more safely than our own. We shall not attempt to consider to what cause this is due; our purpose, for the moment, is to consider whether railway "accidents" are or are not inseparable from locomotion on iron roads; and to do this it will be necessary to define the sense in which we for the moment use the word "accident." We do not intend it to apply to cases where railway servants are crushed between buffers, or are run over when crossing lines; nor to the falling between trains and platforms of persons who insist on entering or leaving carriages in motion; but to refer the term exclusively to those cases in which trains get off the rails. Now, even with these limitations, it will be seen that the subject is a very large one indeed, and will bear examination from many points of view. With a little care, however, certain aspects of the question may be completely eliminated, and the history and progress of railway catastrophes of the more obtrusive kind may be in a great measure simplified, and brought within reasonable limits of reflection.

It is evident, to begin with, that a very large proportion of accidents are due to derailment, and although it is not quite so evident, there is still excellent reason to believe that very many more trains get off the rails in summer than winter. On the other hand, many more axles and rails are broken in winter than in summer, and so the balance is preserved. Indeed, each season of the year appears to have its own special class or type of accidents, and we venture to say that as nothing occurs without a cause, so a careful digest of the statistics and particulars of each season's accidents will be found eminently instructive, and may, indeed, be utilized in designing means of avoiding the occurrence of catastrophes almost or altogether. For example, why should more trains get off the line in summer than in winter? Why should more axles and ties break in winter than in summer? The answer to the last question is very simple. Jack Frost smashes our tires, and axles, and rails, and his mode of operation is well understood. In the first place, whatever theorists may say, it is almost indisputable that iron and steel are more brittle when the temperature is below freezing point than

when the thermometer stands pretty high; and, in the second place, a frost-bound road has little or no resilience or elasticity, and all the shocks which rolling stock encounters as a result of imperfection in permanent way are magnified and intensified in amount. These facts are so well known that on many foreign railways where the winters are intensely cold, the speeds of all trains are reduced to lessen the strains to which the lines and the rolling stock are exposed. So far it is all plain sailing; when we come to consider why it is that more trains get off the line in summer than in winter, it is not a case of plain sailing at all. On the contrary, we are met at every turn by difficulties sufficiently great to almost dispose us to doubt the evidence of our senses, and to assert that just as many trains get off in winter as in summer. If we accept broken rails, tires, or axles, as causes of derailment, it is no doubt true that in winter more trains are off the road than in any other time of the year; but we wish to expressly eliminate such causes of derailment, and to refer exclusively to those accidents in which a train apparently gets off without any reason; and handling the subject in this way, we think we can show that a high summer average of derailment accidents is no more than is to be expected under the existing conditions of railroad construction and working.

If a railway were perfectly smooth, even, and straight, and if the line of draught of carriages passed directly through their centres of gravity, there would be no derailments. Indeed, with perfectly cylindrical tires, and a perfect equality of resistance at every point, flanged wheels would not be required, except to provide for the action of the wind, because there would be no reason why a train, once set fairly on the rails, should be induced to leave them. In practice, however, there is no such thing as a perfectly even and smooth line of rails; the centre of tractive effort does not coincide with the centre of gravity; there are plenty of curves to be run over, and, in short, the road and the rolling stock are both far removed from perfection. Now, all railway men will agree with us when we state that whether a train keeps on the rails or resorts to the ballast instead, at any given speed, is purely a question of the good and bad qualities of the road and the rolling stock. For example, there are tracks to be found, even in England, over which it is not safe to travel at more than 10 miles an hour, and there are also tracks over which we should be quite content to risk our lives at 100 miles an hour. Between these limits there are all kinds of roads, which may be classed as 20 miles, 30 miles, 40 miles an hour tracks, and so on. In like manner there are 20 miles, 30 miles, 40 miles, even 70 miles an hour engines and carriages. If a road were all of the 20 miles, or all of the 40 miles type—of any fixed type, indeed, throughout—the work of running trains would be much simplified, and the risk of derailment would be much diminished. As a fact, however, in the middle of a length of, perhaps, 100 miles of 45 miles an hour permanent way, we come upon a mile, or two of 20 miles an hour road. Over this trains run for years, and safely, apparently at least. No one knows how bad the bad bit is but the driver—there is nothing like standing on a footplate to know where a rough mile comes in. At last it so happens that a 20 mile carriage comes at 45 miles an hour on to the 20 mile bit of road. Then comes derailment, and a coroner's inquest, and a Board of Trade inquiry, and the road is examined, and said to be very good, and the engine-driver is examined, and he says he can't explain it, and the stoker knows nothing about it—stokers never do, *vide* coroners' inquests—and the inspector of permanent way says it is a splendid bit of road; and the foreman of the carriage department is certain that a more perfect vehicle than that which left the rails never was built; and so, according to the evidence, an accident ought not to have happened, and a very little more evidence would convince the jury that no accident ever took place, and would persuade those who travelled by that particular train that they were really enjoying a species of Barmecides feast of contusions, and cut heads, and broken legs, and slaughtered relatives; and, finally, the public are assured that the accident was wholly inexplicable, and another railway company kindly steps in and diverts attention by supplying another accident, which ought not to have happened, but has happened with more sensational characteristics than the first, which is straightway forgotten, attention being concentrated on the second, which only gives way to a third, and so on. The derailment in such cases as these is obviously due to running over a bad bit of road at too high a speed—a thing

which may be done with comparative safety if the vehicles are in first rate order, properly loaded and with wheels in the best possible condition. The fortuitous encounter of a badly running carriage, badly loaded, with a bad bit of road, causes a smash, and the obvious lesson to be learned is that for high speeds both roads and carriages should be in perfect order. Now let us see how all this applies to the fact that there are more derailments in summer than in winter.

In the first place, then, more repairing of the road is done in summer than in winter. There is more renewal and packing of sleepers, and so on. Drivers of engines know very well that there are extremely dangerous places on a road under repair, just where the old and untouched part joins the new. We have often felt an engine lurch right and left, and reel like a drunken navvy, on getting on to a newly laid bit of road which had not had time to settle. In packing all old roads, again, it is the practice to pack them a little too high, to allow for settlement. The first few high-speed trains over a road thus treated "catch it," to use a very expressive if not very elegant phrase. A disturbed road, even when disturbed with the best intentions, is always a dangerous road for high speeds; and a very small gang of platelayers will suffice to reduce a mile or so of road from fifty-mile condition to twenty miles an hour condition in a couple of days. Of course the road settles after a time, and is better than it was before; but while the settlement is going on it is not a safe road for high speeds. If more roads be disturbed in summer than in winter, this is one reason why derailment is more likely to occur in June than in December. In the second place, more trains and longer trains are run in summer than in winter, and as very few railway companies have more stock than they want, all kinds of vehicles are pressed into service, and thus old worn out carriages may be found running in company with first-class stock at first-class speeds. As these inferior carriages generally pay the penalty of utter destruction for their offence when they get off the line, it is not easy to convict them. If the catastrophe takes place at night, the fragments are used to light up the scene, and to destroy every trace of evidence which could convict the erring vehicle. Furthermore, though carriages are run from seaside towns on branch lines, and miserable vehicles which have spent years, perhaps, in pottering backwards and forwards two or three times a day over a couple of miles of road at about fifteen miles an hour, behind a wheezy old cripple of a locomotive, find themselves tacked on to to the tail of a main line train, drawn by a magnificent express engine, and they are thereupon whisked across country sixty or eighty miles without stopping. Is it matter for wonder that the small remains of vitality they possess should be unequal to the strain thus put upon them? So long as the road is good they get on somehow, especially if they are put near the middle of a train and steadied before and behind. At last they come to a bad spot in the road and they incontinently depart from the track and are no more heard of except as so much match-wood. And this running of branch line carriages on the main line in summer is, we admit, another and a most potent reason why more derailments take place in summer than in winter. One other cause and we have done. In summer much longer trains are run than in winter—it was our fate last week to travel in a carriage not new in the middle of a train of 27 vehicles, drawn by two engines, and on one occasion we ran about ten miles at a speed varying between 52 and 59 miles an hour. In theory there is no reason why a long train should be more liable to derailment than a short one; but in practice there is this very serious objection to long trains, that however tightly the draw bars may be screwed up, the buffers will not be in contact when the train is running, because the tension spring is so much compressed by the excessive strain on it. This is the reason why the leading carriages of a long train lurch so much. It is because longer trains are run in summer than in winter that more cases of derailment occur during the tourist and sea-side season than any other time of the year.

What are the lessons to be drawn from these facts? Firstly, that on high speed lines there should be no weak places in the road, and secondly, none but the most perfect rolling stock in the train. A good road will compensate for bad rolling stock, and *vice versa*, and many engineers reckon on the good qualities of their stock to compensate for a bad road; but their sin is sure to find them out. Some day a carriage gets into a fast train which should not get in—bad road and bad carriage meet, only to

part company for ever. No amount of vigilance will provide for such a case. In one word, these first-class speeds require first-class roads and first-class stock. With them, sixty or seventy miles an hour are safe; without them, only a high speed is required to insure the occurrence of an accident, especially in summer.

REPORTS OF ENGINEERS' SOCIETIES.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the annual meeting in November the following list of officers was elected:

Col. Julius W. Adams, President: Col. W. Milnor Roberts and Gen. Theodore G. Ellis, Vice-Presidents; Mr. Gabriel Leverich, Secretary; Mr. James O. Morse, Treasurer; Messrs. John Bogart, Charles Macdonald, and Francis Collingwood, Prof. De Volson Wood, and Mr. Octave Chanute, Directors.

Amendments to the Constitution of the Society, proposed at the regular meeting held October 15th last, were taken up in order, article by article, and the following only were adopted:

ART. 4. Civil, Military, Geological, Mining and Mechanical Engineers, Architects, and other persons who, by profession, are interested in the advancement of science, shall be eligible for admission in their appropriate class.

ART. 16. The active members of this Society shall be divided into three classes, to be styled respectively, Members, Associates, and Juniors; and each person, when duly elected and qualified, shall receive a certificate of membership, indicative of the peculiar class which he represents. Associates and Juniors shall possess all the rights and privileges of Members, excepting the right of voting.

ART. 17. To be eligible as an Associate, the candidate must be one whose connection with science or the arts qualifies him to concur with civil engineers in the advancement of professional knowledge. To be eligible as a Junior, the candidate must have been in the actual practice of his profession for at least two years.

ART. 19. All candidates for admission to the Society must file statements by themselves, setting forth the grounds of their claim to be elected; be proposed by at least two Members of the Society, to whom they must be personally known, and a notification of the same sent to each member whose place of address is on record. Each proposition, with the names of the proposers, must be posted in some conspicuous place in the rooms of the Society, for at least thirty days before being submitted to vote. All such papers and applications shall be laid before the Board of Direction, and be reported upon, previous to action by the Society.

ART. 20. In elections for membership of either class, Members shall vote by letter, or by ballot in the usual way, and the result shall be announced at the next regular meeting held after thirty days have elapsed from the time of mailing the notification. Three or more ballots cast in the negative shall exclude. Members notified but not respond-ing, shall be classed as having voted in the affirmative.

ART. 22. Persons thus elected and duly qualified, who reside in the City of New York, or within fifty miles thereof, shall be deemed Resident; and those who reside beyond those limits shall be deemed Non-resident.

ART. 23. The amount of entrance-fee to be paid, as well as the annual dues or assessments for the support of the Society, shall be determined from time to time, at some regular meeting of the Society, provided that notice of intended action thereon shall have been given at a previous regular meeting. No alteration in the amount of said fees or assessments shall apply to the fiscal year during which it is made, but shall take effect on and after the first Wednesday in November next succeeding the day of the date of said alteration.

ART. 29. Resident Members, Associates or Juniors, who may remove beyond the limits prescribed in Article 22, for the term of one year or more, shall be subject to the payment of such fees and assessments only as are prescribed for Non-residents, provided that the person thus removing shall give the Secretary of this Society written notice of such removal. This privilege, however, shall not apply to any fractional part of the fiscal year.

ART. 30. Every person admitted to the Society shall be considered as belonging thereto, and liable to the payment of all assessments, until he shall have signified to the Secretary his desire to withdraw; when, if his dues have been fully paid up, his name shall be erased from the list of members.

ART. 31. Any person admitted to the Society, who shall refuse to pay any assessment or other dues to the Society, or who shall neglect the same for the term of six months, after due notice is issued in the Form C, in the Appendix, shall cease to be a member.

ART. 35. Proposed amendments to this Constitution shall be first submitted to the Society, and seconded, and then sent by letter to the several Members of the Society, at least twenty-eight days previous to the Annual Meeting. Such amendments shall be in order for discussion at such Annual Meeting, and shall be voted upon by letter-ballot, within sixty days after the date of said meeting. The votes shall be counted by the President and Secretary, and if two-thirds of the votes are in favor of said amendment, it shall be declared adopted, and the result announced at the next regular meeting of the Society thereafter.

ENGINEERS' CLUB OF THE NORTHWEST.—Mr. E. S. Chesborough recently read a paper before this Society on Conveyance of Water and Repair of Pipes under Navigable Streams.

The existence of navigable streams in the heart of a city had, until late years, been considered a great obstacle to the conveyance of water by pipe across them. Wherever fixed bridges were used, the pipe could be carried across without difficulty, but where there were draws it would be necessary to have pipes along the bottom or in tunnels. The Babylonians are said to have had a tunnel beneath the Euphrates, but very little is known about it. The earliest instance of carrying water across streams was that of Watt, of Glasgow. The next instance, as in the case of Watt, by flexible pipes, was that employed by W. S. Whitwell, be-

tween Boston and Chelsea. Ward's joint, a comparatively recent invention, by its economy, simplicity and inflexibility, has come into general use for flexible pipes, and has several patented improvements. Another plan adopted at the crossing of the Charles and Mystic rivers by the Boston Water Works, was to lay the pipes by the side of existing pile bridges, above high water mark across the shallow portions, and to place inverted syphons under the channels at the draws. These, put together on shore, were made by boxing around the pipe with heavy timber, having a sufficient space between the pipe and wood to be filled with cement to protect the iron from the salt water. All pipes under water should be provided with some means of removing deposits. When not large enough to admit a man, they should be provided with "blow-offs" near the surface of the water. The great importance of being able to reach at all times a break or defect has led to the adoption of tunnels under navigable waters. The first on record in this country appears to have been that of Eddy, of Boston, passing under the Charles river, though there are now many in use in this country and Europe. Mr. C. described some of the difficulties of repairing pipes beneath the surface, illustrating the subject by reference to the leaks repaired in the Chicago avenue and Rush street pipes beneath the river in the city. In these cases the pipes first used were simply of boiler iron, joined and sunk into trenches, formed by dredging. They were often injured by anchors, driving piles, etc., and therefore tunnels have been made at Rush street, Adams street, Chicago avenue, Archer avenue, and two beneath Division street. There is also a 36-inch pipe through the La Salle street tunnel. The other pipes are 24-in., laid in tunnels 6 ft. in diameter. This gives room for workmen to make repairs.

IRON AND STEEL NOTES.

With reference to the tensile strength of Lake Superior iron, the Detroit "Free Press" makes a record of the following experiments with iron made from Lake Superior ores, by the Wyandotte Company. A bar of railroad iron was put under the hammer, and bent, twisted, and tortured until no resemblance of the original bar remained. An effort was then made to hammer the head of the rail from the flange, but it proved unsuccessful. It must be understood the experiments were made when the iron was cold. The experiments with the chains were equally satisfactory and showed a great power of resistance. A Bessemer steel chain, 1¼ in. in thickness, withstood a test of 121,850 lbs. to the square inch. The following comparisons will show the relative tensility of Lake Superior and English iron, the trials having been made by the use of the testing machine made by Riehle Brothers, of Philadelphia, which is that used for all tests in which the American Government is concerned. A one-fourth inch chain of American (Lake Superior) iron withstood a strain of 101,750 lbs., while a chain of English iron of the same size broke at a test of 76,500 lbs. A five-eighth inch chain, American, 24,875 lbs.; English, 16,000 lbs. A three-fourth inch chain, American, 38,000 lbs.; English, 26,000. A one-half inch chain, American, 15,825 lbs.; English, 8,500; and a seven-sixteenth inch chain, American, 10,250 lbs.; English, 5,750.

Preservation of Sheet-Iron.—The results of some experiments in regard to the preservation of sheet-iron used in railroad bridges have been published by the Directorate of the Government Railroads of the Netherlands. From thirty-two sheets half was cleaned by immersion for 24 hours in diluted hydrochloric acid; they were then neutralized with milk of lime, washed with hot water, and while warm dried and washed with oil. The other half was only cleaned mechanically by scratching and brushing. Four of each kind were then equally painted with red lead, with two kinds of red paint of oxide of iron, and with coal-tar. The plates were then exposed to the weather, and examined after three years. The result was:—1. That the red lead had kept perfectly on both kinds of plates, so that it was impossible to say if the chemical cleaning was of any use. 2. That one kind of iron oxide red paint had better results on the chemically treated plate than on the other: in fact, a result equal to that of the plate painted with red lead, while the other kind of iron oxide red gave not very good results on the plates, when only scratched and brushed. 3. That the coal-tar was considerably worse than the paint, and had even entirely disappeared from those iron sheets which had not been treated chemically, but only cleaned by brushing.

Steel Boiler Plates.—Mr. L. R. Haswell, Engineer of the Austrian State Railway Company, in an address delivered before the Society of Austrian Engineers, remarked that the accidents which had occurred on railways using locomotive boilers of steel had thus far been only ascribed to the material; yet this was due, on the one hand, to the preparatory working of the plates, and on the other, to the small thickness, as well as to the insufficient mode of assorting them before they were used. The State Railway thus far has used about 50,000 cwt. steel plates, among which only 200 cwt. were thrown aside during the manufacture of the boilers. Mr. Haswell only knows of five instances where such boilers got cracks, four of which occurred in the fire-box-plate and one in the cylindrical part. He ascribes their faulty condition to the fact that they were rolled when too warm. This shows that even by purchasing steel plates from the most renowned establishments and of the best quality, one cannot depend on their superiority for the purpose in question, without assorting them with the utmost care, because it can readily occur that in heating the plates one or more get spoiled. Hence, in the establishments of the State Railway all plates are subjected to tests for their tensile strength before they are used. That these tests are perfectly reliable is shown by the fact that of 350 boilers consisting of steel plate, only a single one was found torn thus far, and this in the cylindrical part. The box plates not having been tested, it is readily explained that four boilers were injured in those parts. But, although these plates had undoubtedly been impaired in their strength by overheating, they would probably not have been torn if the construction of the machines, namely, the boiler supports, did not involve an immense strength.

In order to obtain steel boilers answering all requirements, only correspondingly thick plates and plates of the best material, without any addition (for otherwise the steel is not homogeneous), ought to be used; they ought to be scrupulously assorted according to the texture and tensile strength. After boring, or punching, they should be carefully annealed, the riveting must be performed with pedantic care, and the bending only with wooden hammers. That steel plates manufactured in Austria are of excellent quality is proven by the manner how boilers are there constructed; the box front plate, down cover, and the sides of the tubes are only furnished with an edge, or border, while in England they are compelled to use angle iron for these connections.

Steel plates are preferable to iron plates, owing to the fact that they possess the same degree of elasticity in all directions (from 12 to 15 per cent.); in iron plates it is in the direction of the fibres, and according to Kirkaldy, about 15 per cent., but in a cross direction only 5 per cent. If one proceeds in the manner indicated, says Haswell, steel plates may be used with perfect safety. The boiler manufacturer has the advantage that he finds less plates to throw aside, and the railways, on the other hand, will have more carefully constructed, stronger, and, in the end, cheaper boilers.

PATENT FURNACE TOP.—We hear good accounts of the working of Harris' Patent Furnace Top. Aside from the increased convenience in working the furnace, a great gain in economy is claimed by many who have used the "Top" during the past two years.

THE IRON TRADE.—From the annual report of the Iron and Steel Association, we make the following brief abstracts:

The year 1872 opened with an increased demand for iron in nearly all civilized countries. Prices advanced rapidly in all markets. The supply was unequal to the demand, although production was everywhere stimulated. In the United States forty new blast furnaces were erected, and the erection of others was undertaken—the foreign demand for British iron and the increased cost of producing that iron leading to the reasonable presumption that our people would now be able to possess their own iron market.

PRESENT CONDITION OF THE IRON TRADE.

The high prices for iron of all descriptions which had prevailed in the United States in 1872, gradually declined during the latter part of that year, and this decline, with some effort at a rally in January, continued during 1873.

The production of pig iron in the United States in the year 1872 was 2,830,070 net tons, or 2,526,848 gross tons. This quantity was produced in twenty-one States. The ascertained production during the first 6 months of 1873 was 1,393,075 net tons, and the estimated production for the whole of the year 1873 is 2,695,434 net tons, or 2,406,637 gross tons. The number of States which made pig iron this year was twenty-two—Maine having re-entered the list after a long rest. The excess of production in 1872 over the estimated production of 1873 is 134,636 net tons. If the financial crisis had not occurred, the production of 1873 would have exceeded 3,000,000 net tons. The estimated annual capacity of all the furnaces in the United States is 4,371,277 net tons.

The total number of furnaces in the United States, exclusive of abandoned and projected furnaces, is 636. The total number of new furnaces finished and put in blast in 1872 was forty-one; finished and put in blast in 1873, forty-two; total number of new furnaces put in blast in the last two years, eighty-three. Many of these are among the largest in the country. By the erection of these eighty-three furnaces, the furnace capacity of the country has been increased fully one-fourth.

Pennsylvania still maintains her position at the head of the States which make pig iron. In 1872 and again in 1873 her furnaces produced very nearly one-half of the total yield of the whole country. The three Western States of Michigan, Wisconsin and Missouri, with sixty-four furnaces, have this year made one-tenth of the total yield.

There is one furnace in Texas, which is making pig iron this year. It is situated near Jefferson, in Marion county. A letter to this office from Mr. H. C. Hynson, of Jefferson, states that extensive and valuable iron mines exist near that place, which can be bought at five dollars an acre. Coal can be obtained at fair prices, and excellent railroad facilities exist. The Texas and Pacific Railroad will undoubtedly open up rich deposits of both iron ore and coal in Texas. Over two hundred miles of this road are now finished and in operation.

It is somewhat remarkable that there is no furnace in Delaware. Forty years ago there were many charcoal furnaces and other iron works in Sussex county, in this State, which produced iron of the best quality. There is yet an abundance of excellent ore in the county, and both anthracite and bituminous coal can easily be obtained for smelting it.

Summary of Iron and Steel Production.

Below is a summary in net tons, of the ascertained and estimated production of iron and steel in the United States in 1872 and 1873:

	1872.	1873.
Iron and steel rails	941,992	850,000
Other rolled and hammered iron	1,000,000	980,000
Forges and bloomaries	52,000	50,000
Cast steel	32,000	28,000
Bessemer steel	110,500	140,000
Siemens-Martin steel	3,000	3,500
Pig iron	2,830,070	2,695,434

Railroad Construction.

We estimate the mileage of new track for the year 1873 at only 3,000 miles, a decrease since last year of more than 50 per cent. The year 1871 witnessed the culmination of railroad construction in this country. The number of miles built in that year was 7,779. The reaction commenced in 1872, when 6,427 miles were built. The total railroad construction of 1874 is estimated at 3,000 miles, the same mileage as the estimate for 1873.

RAILWAY NOTES.

THE INTERNATIONAL BRIDGE FINISHED.—The Buffalo "Commercial" announces that the great International Bridge, crossing the Niagara River at Black Rock, and connecting the United States of America with the Dominion of Canada, is at last completed. The first caisson was launched on the 13th of July, 1870, and work progressed steadily up to the time of completion. The bridge was practically finished this week, by the winding up of work on the last span. The entire cost of the International Bridge, in round numbers, is not less than $1,500,000. Of its practical benefits we leave the reader to judge, merely stating in conclusion that it supplies a want long been felt by the different railroads which have for so many years been obliged to cross the Niagara River on the steamer International. The bridge has been leased to the various railroads which will cross it, for twenty years. The roads are the Grand Trunk, the Great Western, the Canada Southern, the New York Central, the Erie, and the New York, West Shore and Chicago. Most of these railroads have already constructed their approaches to the bridge, and will commence sending trains across at as early a day as possible. A railway track is laid over the bridge, and also a sidewalk for foot-passengers. The original plan contemplated a carriage-way as well, but this was abandoned for the reason that, as the bridge was three-quarters of a mile long, and so many trains were to cross it, there would very seldom be a chance for carriages to cross without interfering with the trains. Hence it was thought best to give up the idea of a carriage-way altogether.

ENGINEERING STRUCTURES.

THE BALTIMORE BRIDGE COMPANY have built within the year 1873, 55,000 ft. of bridges—nearly 10½ miles of iron structure.

Many different plans are represented in these bridges, including the Fink, Pratt, Howe, the Warren Girder, and other triangular systems not designated by any distinctive title.

Included in the above is the Varrugas Viaduct, on the Lima and Oroya Railroad, the iron pieces of which are 252 ft. high.

THE IRON BRIDGE AT BOONEVILLE, MO.—From a letter of Mr. D. C. Brookes to the Chicago "Railway Review," we take the following:

Probably the most extraordinary "feat" in bridge building ever performed in this or any other country is that now approaching consummation in the construction of the bridge across the Missouri River, at this point, by the Missouri, Kansas & Texas Railway Company. Here is an iron truss bridge 1,638 ft.—or more than one-third of a mile—in length from centre to centre of abutments; resting on piers partly of stone and partly of iron pneumatic tubes, and having a draw with two openings of 160 ft. each in the clear—wholly completed (if finished, as is assured) by January 1st next, in the brief period of about *ten* months. This unexampled progress is due (not omitting, of course, to recognize the energy of one of the most enterprising of the great railway companies of the West, possessed of the ready money to command every facility and to improve every moment of time) to the facts that the topography and *regimen* of the impetuous current of the Missouri were now thoroughly understood in the light of previous successful attempts; that the best known, and, doubtless, best possible modes of sinking foundations, whether of stone or iron, through deep and shifting sands to the solid rock bed had been arrived at; and that the railway company availed itself of the services of engineers thoroughly experienced in every process required, seconded by the efforts of an organization (the American Bridge Company, of Chicago) whose history is peculiarly identified with bridge construction over the Missouri River. The work has been prosecuted under the immediate supervision of Mr. O. B. Gunn, the Chief Engineer of the Missouri, Kansas & Texas Railway Company; with William Sooy Smith as engineer of the bridge, and the American Bridge Company as the contractors for the work. In the months of October and November, 1870, General Smith made the preliminary surveys, and selected the location for the bridge. Work was not actually begun till Sept. 1872; and very little was done, except in the way of preparation, until the opening of the spring of 1873. From that time to the present, work has been literally "pushed,"—being carried on night and day, week in and week out, without even a Sabbath day's rest.

On the line chosen for the bridge a table of rock extends from the south bank (here quite precipitous) out under the stream 500 ft., with a depth of water thereon, at low water, of from 10 to 15 ft.; for the next 200 ft. the rock drops off to a depth of 33 ft. below low water; and from thence to the north bank to a depth of 54 ft. below low water. The width of the river at low water is 1,000 ft. and at high water 1,600 ft., and the total length of the superstructure is 1,639 ft. The location from bank to bank is 3,200 ft. Besides the main channel, there was in the natural state of the river a secondary channel of 1,000 ft. on the north side, with an island 700 ft. wide between. In locating the bridge it was decided to fill up the secondary channel, and also to fill in partly across the island, making a heavy dyke, thus—by entirely damming the secondary channel—throwing all the water into the main channel on the south side of the island. This dyke was completed about the 1st of January last, before the annual rise. The effect of the high water was to completely scour out the sand bar obstructing the main channel, greatly to the benefit of navigation; also to scour out the sand from off the rock, leaving it bare at (pivot) piers 1 and 2. The dyke, containing 125,000 cubic yards of earth, has its slopes thoroughly riveted with brush as at the St. Joseph Bridge)—no stone being used—to 4 ft. above high water. The water this year was the highest since 1867; yet no damage occurred to the dyke. The effect on the river has been to form a heavy natural dyke across the upper end of the slough, one mile above the bridge, and also across the lower end 1,000 ft. below the bridge, thus shutting the water off from the slough entirely.

The bridge consists of eight spans: 2 (fixed) of 248 ft. each; 3 do. of 235 ft. each; a draw span (two openings), having a total length of 363 ft.,

and an approach span on the north side of 84 ft., making a total length of 1,638 ft.

The following are the total quantities used in the substructure:

First class masonry, cubic yards	4,222
Concrete, cubic yards	2,354
Riprap, cubic yards	2,268
Earth embankment (approaches)	110,000
Timber (in feet board measure)	482,576
Pneumatic cylinders (lineal ft. 668) tons	600
Wooden piles (foundation of abutments), lineal feet	2,652
Wrought iron drift bolts, etc., lbs	60,606
Cast-iron braces, washers, etc., lbs	24,300

The eight spans composing the bridge are all of iron: Post diagonal truss—outside intersection; top chord, cast iron; bottom chord and ties, wrought iron. The assumed strength of the wrought iron is 60,000 lbs. per sq. in.; assumed strength of superstructure, 2,100 lbs. per lineal ft.: assumed weight of moving load, 2,500 lbs. per lineal ft. All the iron in the bridge is tested to double the estimated strain which it will receive beneath the maximum load; all materials used at a safety factor of 6.

ORDNANCE AND NAVAL.

THE RUSSIAN CIRCULAR SHIP.—The Russian circular iron-clad ship Popowka is a turret vessel, flat-bottomed, 97 ft. in diameter, and of 2.491 tons. Her draught of water is estimated at 12½ ft. The hull is to be protected by 7-in. armor, and the turret by 9-in. plates. The ship will be driven by six screws equidistant from each other, and each worked by 80-horse power engines, the whole motive power being 480-horse power. A ram-shaped beak forms the bow, and at the opposite extremity of the diameter a rudder-post and rudder is fixed. The armament is to be two 11-in. Krupp steel breech-loading guns, throwing 500 lbs. shot, and worked in a fixed turret. The object of this circular construction is of course to carry a more perfect armor protection on a comparatively light draught of water and small tonnage. The keel was laid at St. Petersburg, in May, 1871, and the vessel is expected to be ready for her steam trials in the course of this year. Much interest will be excited in this country as to the results of this experiment. We need hardly say that the idea of building a circular ship is by no means novel, but the possibility of attaining respectable speed has been always seriously doubted. On the other hand, with an equal thickness of armor the circular ship would be less burdened by the weight, and the difference of displacement might, it has been urged, be employed in extra engine power. This, however, has not been done in the Popowka. Unless the indicated horse-power be vastly greater than the nominal power given, we can hardly think she will attain a high speed. The Popowka is only 150 tons less tonnage than our own Hostpur, which has 600 horse-power engines, and though nearly double the beam of the Hostpur the circular ship has 120 horse-power less engine power. The fixed turret of the Hostpur has also been given up as a mere shell-trap with four large openings for the admission of projectiles; and we should imagine that the most favorable type of vessel for a revolving turret would be a circular ship. This detail may possibly be reconsidered before completion. Should the Popowka turn out even a partial success, the principle of circular iron-clads has so much to commend it, that the experiment may deserve repetition under more favorable conditions. The principle of diminishing the area of armor protection to ordinary broadside ships, in order to thicken the plates, is thought by many to have been carried far enough as regards the hull. The present reduced belts leave vital parts above and below them exposed to view in the most ordinary weather at sea. Shot-holes might easily be made immediately below or above the belts near the extremities, which, in the heave of a sea swell, would admit water very freely. The width of the belt cannot therefore be farther diminished with safety, and if the only object of a ship of war was to keep out shot, the circular ship would seem the most natural means of carrying the heaviest weight of armor on the smallest draught of water. That the Popowka may present advantages in the shallow waters of the Baltic, or in bombardments, or for coast defence purposes, is evident. But it does not at all follow that such a vessel could frequent the open sea, or take part in a general engagement with safety. It is, for example, obvious that the Popowka would be more easily rammed by a hostile ship than the Hostpur, for whereas the latter ship could only be destroyed by a ram striking her within a small angle of the perpendicular to either broadside, and could by a slight movement of her helm increase that angle rapidly to the safety arc, the Popowka is open to attack by rams on any diameter, and could be struck at right angles to the circular side at the point of impact, however the vessel was turned. The Popowka cannot, in fact, present her side at a safety angle to a ship which steers for her central turret; whereas the Hotspur is safe against rams for at least half the circle. If, in addition to this, we credit the Hostpur with higher speed, and reflect that the force of impact is represented by the difference between the speeds of the attacking ram and the attacked ship, the advantage on the side of the broadside ship in such a contest will be still more evident. On the other hand, the circular ship will have an apparent advantage in using her ram, in consequence of the great ease with which she can change her course, so as to present her beak to a vessel trying to avoid the attack. But this advantage is limited by the circumstance that the greater breadth of bow (if we may so call it) covers the action of the beak, and would necessitate an approach by a more direct path. This limitation of the angle of approach will be evident when it is reflected that the long lean bow of an ordinary ship admits of the beak being used freely at every perforating angle; while the circular ship is not only double the breadth, but carries that breadth almost up to the beak itself. The great advantages of the Popowka over the Hotspur will be 7 ft. less draught of water, an enormous gain in coast defence or coast attack, and probably in seaworthiness. This latter point is regarded by sailors as the first essential of a ship, and as more essential in vessels designed for the defence of stormy coasts, than in those intended to operate in the open sea. With 19 ft.

draught of water, shelter is denied to the Hostpur by most of our rivers, estuaries, and creeks. Land under the ice is a source of imminent danger in a storm when its harbors cannot be entered, for then the rocks to leeward rather than the ease of the ship governs the seamanship of the situation. A ship on a lee shore does not get so fair a chance of life as one in the mid-Atlantic. Yet the custom has arisen of classing every unseaworthy ship-of-war which is unhappily launched as a "coast defence" vessel, until unseaworthiness and coast defence have become synonymous terms. It is, indeed, worthy of Mr. Plimsoll's consideration, whether the proposed Act to prevent unseaworthy and overladen ships proceeding to sea ought not also to apply to the Royal Navy. If an unseaworthy and overladen ship may not carry a dozen men and a cargo of coals from Newcastle to Portsmouth, why should an unseaworthy and overladen ship-of-war be permitted to carry 150 men and a cargo of guns and armor from Portsmouth to Newcastle? Whether the Popowka will prove less unseaworty than so many of our low freeboard vessels is not, as regards the construction of circular ships for our own fleet, the least interesting point to be watched for in the coming trials. Whatever be the result, the Russian Government and its naval constructive advisers are to be congratulated on the boldness which dictates this courageous experiment. We trust that, having ventured upon this expensive proceeding, they will not emulate the inertia of our own Admiralty under like circumstances, but exhaustively investigate the several merits and demerits of circular ships; so that valuable experimental data may be accumulated under the guidance of scientific seamen, which shall lay the foundation of true knowledge on a subject long agitated, but of which little, if anything, is actually known.—*Iron.*

THE ORDNANCE REPORT ON RIFLES AND HEAVY ORDNANCE.—General Dyer, Chief of Ordnance, in addition to portions of the report already published in these columns, says: On the subject of small arms, in conformity with the provisions of the Act of June 6, 1872, appropriating $150,000 for the manufacture of arms at the national armory, a Board convened in New York city September 3, 1872, and concluded its labors May 5, 1873. After an exhaustive examination and trial during a session of months' duration, of over 100 arms, including those adopted by the first military powers of Europe, the Board resolved that the Board recommend that the Springfield breech-loading system be adopted for the military service of the United States, in accordance with the provisions of the Act of Congress approved June 6, 1872. The Springfield Arsenal is now engaged in the manufacture of rifles and carbines on the new model for the military service. Ten thousand of these arms will be supplied to the army for trial. The report says respecting heavy ordnance: The importance of the subject increases with the earnest and continued efforts on the part of all nations, not only to improve the quality of the guns, but in providing in quantities those that have given best results in experimental trials. It is not the part of wisdom to wait for ultimate perfection in gun constructions, which may never be attained, or for the first rumbling of approaching strife, when guns are needed in fortresses and not in foundries, to commence the tedious and costly work of construction. In the modern quick and decisive settlement of differences by the arbitrament of arms there is no time for preparation after the declaration of war, and a nation may sink beneath the powerful blows of a well armed adversary in less time than it takes to manufacture a single gun.—*Iron Age.*

BOOK NOTICES.

A TREATISE ON THE METHOD OF GOVERNMENT SURVEYING. By S. V. CLEVENGER, U. S. Deputy Surveyor. New York: D. Van Nostrand. (In Press.)

This work is designed to be a guide to the methods of surveying public lands, as prescribed by Congress and the Commissioner of the General Land Office.

The following table of contents will explain to what extent the author has discussed the practical details of the subject.

PART I.—Introduction—Initial Point—Principal Base—Principal Meridian Standard Parallel — Guide Meridian — Independent Meridian — Township True Lines and Randoms—Subdividing into Sections—Subdivisional Random Lines—Subdividing into Quarter Sections—Meandering Irregularities and Expedients.

PART II.—Triangulations—Traversing Meanders—Astronomy used in Surveying—Uses of Logarithms—Converging and Diverging—Vernier Reading.

PART III.—Vernier Compass—Solar Compass—Flagging—Chaining—Blazing—Corner Building—Witness Corners—Meander Corners—Blazing Trees or Objects—Bearing of Land or Water Objects—Closing Limits—Outfitting—Topography—Tablets—Field Notes.

PART IV.—Tables—Logarithms—Logarithmic Tangent and Sine Tables—Traverse Table—Natural Tangents Convergencies Length of Degrees of Longitude—Refractions—Equation of Time.

LIGHT SCIENCE FOR LEISURE HOURS (Second Series.) BY RICHARD A. PROCTOR, B. A. London, 1873. For sale by D. Van Nostrand. Price, $3.75.

This last book of Mr. Proctor's is in no way less interesting or instructive than those which have preceded it. It is better adapted to the comprehension of the general reader than the treatise on the Moon.

Mr. Proctor thinks out his conclusions so often and so intuitively, by aid of double integrals, that it must cost something of an effort to eliminate the higher mathematics from his astronomical essays. But one who has read only his articles for the standard periodicals would hardly suspect this; the most familiar and unmathematical illustrations are employed to elucidate difficult points in physics and astronomy, and used with rare success. The student who has read "Saturn and his System" knows something of Mr. Proctor's powers of analysis, and has learned to respect the opinions set forth, although the science is so *light* that it may be comprehended by the novel reader.

Of the present series, the chapters on "The Gulf Stream," "The Ever Widening World of Stars," "The Great Nebulæ in Orion," "Something Wrong with the Sun," and "News from Herschel's Planet," are worth the cost of the boook.

HOW TO BECOME A SUCCESSFUL ENGINEER. By BERNARD STUART. (Sixth Edition.) New York: D. Van Nostrand. Price, 50 cents.

The inquiry most frequently made by young men, at least the one with which we are most familiar, is, "What is the necessary education for an engineer?" This the little book of Mr. Stuart answers quite clearly. And whether the inquiry refers to mechanical or civil engineering, the reply is equally explicit.

The several topics: The Education Preliminary to Practice—Special Education Technical Education, Workshop and Workshop Practice—The Education of the Civil Engineer, are all exhanstively treated and will be found profitable reading even by the engineer of long practice.

FREE HAND DRAWING. A GUIDE TO ORNAMENTAL, FIGURE, AND LANDSCAPE DRAWING. By AN ART-STUDENT. New York: D. Van Nostrand. Price, 50 cents.

That this is the second edition is testimony to the value of this little book. It presents the rudiments of the art of drawing by familiar examples in a style not to be misunderstood by the merest tyro.

The separate topics are: Materials Employed in Drawing and how to Use Them—On Lines and how to Draw Them—On Shading—Concerning Lines and Shading with Applications of them to Simple Elementary Subjects—Sketching from Nature.

The illustrations of the progressive exercises are numerous and well executed.

THE BORDER-LAND OF SCIENCE. By R. A. PROCTOR, B. A. London, 1873. For sale by D. Van Nostrand. Price, $5.25.

Mr. Proctor has here collected a number of the popular papers on scientific topics contributed by him to the pages of the "Cornhill Magazine," where they have probably come under the notice of some of our readers. Mr. Proctor's specialty forms the subject of the major part of them; but one, at least, is within our own field, and particularly interesting to everybody at present: we allude to the "Few Words about Coal," in which the author, after an instructive sketch of the nature and origin of that useful mineral, proceeds to discuss the urgent question of our coal supply, so far as concerns the availability of the still untouched stores, as depending on the depth to which mining operations can be pushed. Accepting the dictum of the Commissioners on the Coal Supply, that 3,000 ft. is about the lowest depth at which, owing to the increase of temperature, coal can be worked, and that the quantity thus available must be reckoned at something less than 150,000,000 tons, he yet demurs to the conclusions arrived at by these officials, and by Messrs. Jevons and Hull, as to the probable rate of increase of consumption, holding that although for many years to come, the average rate may be expected to be fully equal to that at present observed, yet, before many years are passed, that rate (then higher than now) will be beginning to diminish, thenceforward returning towards its present rate, and passing eventually below it. And as the extension of the employment of coal for known uses has in several cases nearly approached a limit, a reduction in the rate of increase of consumption would, he maintains, not necessarily imply a falling off in the commercial and manufacturing prosperity of the country, but the reverse, just as though a merchant whose gains had been increasing by £1,000 a year should find them still increase by £900, £800, £700, until the increase settled down to some constant or nearly constant sum, such as £200. In this way he extends the period of exhaustion fixed by the Commissioners as less than 280 years, to a millennium, adding that "1,000 years of prosperity is a future which this nation might contemplate with satisfaction."

TREATISE ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY. By W. TIMBRELL PIERCE, Architect. With eighty-five plates. London, 1873. For sale by D. Van Nostrand.

The author of this treatise is of opinion that a good text-book on the subjct of Practical Solid Geometry is much wanted for English students; but, remenbering the many works on Geometry published during the last few years, we should scarcely have thought so. The present treatise embraces orthographic projection and perspective, or radial projection; and Mr. Pierce proposes in a future work to show the application of the subject to the several arts of construction. Having been lecturer on geometrical drawing at King's College, London, and at Harrow School, the competency of the author to deal with his subject is certain.—*Builder.*

SIKHIM, WITH HINTS ON MOUNTAIN AND JUNGLE WARFARE. By Colonel J C. GAWLER, F. R. G. S. (London: E. Standford.) For sale by Van Nostrand. Price, $1.75.

This is a narrative of the Sikhim expedition under Colonal Gawler in 1860, which the gallant commander now publishes as a tribute to the heartiness, energy, and excellent conduct on the part of the officers and men, by means of which the compaign was brought to a successful and happy termination. A good part of the book consists of the official reports, published by permission of the Secretary of State for India; and in these and the connecting narrative will be found much that will be interesting to the general reader, and likely to prove useful to officers engaged in offensive operations in a similarly mountainous and densely wooded country. On a somewhat controverted point, of peculiar interest at the present time, Colonel Gawler speaks decisively and with the authority of success. He maintains that, properly directed, the disciplined and clothed British soldier is more than a match for the naked, undisciplined savage, in the bush, as well as in the open. "If the officer turns the discipline of his men to account, and dashes with them into the bush, the necessary fighting odds of the savage are at once reduced and the soldier is every moment on more even terms with him, to try him at close quarters, if he stand, which he never does." With respect to the advantage given by clothing in such circumstances, Colonel Gawler says that, when in command of Kaffirs, in active service, he found

that "the unshod and half-clad savage has a very great dislike to leaving the footpath for the unbeaten bush, particularly if it be wet from rain or dew. It tears his skin, and thick though they be, the soles of his feet become spongy with wet and are soon penetrated by thorns." We quote the description of a novel species of suspension bridge across the river Teesta, which has an exceedingly elegant appearance in the illustrative engraving. The natives are said to construct a bridge with surprising speed and facility. The one in question consisted, first, of two parallel arches, 10 or 12 ft. apart, each constructed by securing a bundle of long bamboos (say 60 ft. long) by the butts in the bank on either side of the river and then bending them down across the river, making the thin ends overlap, and tying them fast; secondly, from the two arches so formed, are suspended bundles of bamboos, firmly lashed together, and also arched slightly, forming the footway. Two rails make all safe. It is described as far more comfortable than the ordinary cane suspension bridge, and easily practicable for horses and cattle.—*Iron.*

A MECHANICAL TEXT-BOOK; OR, INTRODUCTION TO THE STUDY OF MECHANICS AND ENGINEERING. By W. J. M. RANKINE, C. E., and E. F. BAMBER, C. E. London, 1873. For sale by Van Nostrand. Price, $3.50.

This text-book is primarily intended as an introduction to more abstruse works on the same subjects, in particular to those of Professor Rankine, which hold a very high rank. The matter is arranged in six divisions, the principles of cinematics, the theory of mechanism, the principles of statics, the theory of structures, the principles of kinetics, and the theory of machines, embracing the whole field of mechanics and engineering, the principles and practice of which are explained in a manner at once lucid and comprehensive. Mr. Bamber, whose name appears as the joint editor, lectured for Professor Rankine during his last illness, assisting him also in the preparation of this work. At the time of Mr. Rankine's death, its general scope and plan had been decided on, and 200 pages completed, and that plan has been implicitly followed out by the survivor.

THE GAS CONSUMER'S MANUAL, AND ON SETTING AND WORKING RETORTS. London. For sale by Van Nostrand. Price, 75 and 50 cents.

Are pamphlets on the subject of Gas and Gas making, by Mr. E. S. Cathels, C. E., of the Crystal Palace District Gas-Works, Montreal. In the first of these the writer considers the important question involved in the obtaining of good and cheap gas, and after succinctly stating the principles on which all improvements must be based, enters minutely into detail as to burners and their construction, the use of globes, governors, etc.; his conclusion being that the "London" self-regulating flat flame, or argand burner, with Sugg's albatine shades, may justly be characterized as the very triumph and luxury of gas-lighting. Mr. Cathels states in his preface that it is estimated that the number of deaths in the United States in 1872 from explosions of lamps (burning unrefined mineral oil, we presume), was 5,200, besides 20,000 persons maimed or otherwise injured. Second only in importance to gas-lighting, the writer considers cooking by gas. He maintains that this has advantages in convenience, cleanliness, and economy as great relatively in the case of the smallest family as the largest public institution if the gas be but properly burnt and carefully used; and describes and sketches a number of handy appliances for this end, concluding with plain instructions, doubtless necessary, in many instances, to householders as to the use of gas-meters. The other brochure is a reprint of a paper on the subject expressed in its title, read at the seventh annual session of the British Association of Gas Managers, in which Mr. Cathels, after repeating the history and explaining the principle of the operations referred to, describes and recommends a system of his own.

MISCELLANEOUS.

DEPOSITS IN BOILER FLUES.—Professor Hayes gives, in the "American Chemist," the following opinion regarding the formation of these deposits. They are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and contains a large proportion of iron if the deposit is an old one, or very little iron if it has been recently formed. The other has a basis of soot and fine coal ashes (silicate of alumina) filled with sulphur acids, and containing more or less iron, the quality depending on the age of the deposit. The pyroligneous deposits are always occasioned by want of judgment in kindling and managing the fires. The boilers being cold, the fires are generally started with wood, pyroligneous acid then distils over into the tubes, and, collecting with the soot already there from the first kindling fires, forms the nucleus for the deposits, which soon become permanent, and more dangerous every time wood is used in the fireplace afterward. The sulphur-acid deposits derive their acids from the coals used, but the basis material, holding these acids, is at first occasioned by cleaning or shaking the grates soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compounds distilling from the coals, and the corrosion of the iron follows rapidly after the formation of these deposits.

STEEL bars have been advocated in place of bells for churches and similar purposes. They produce a pure, distinct and melodious sound, and are said to be cheaper, lighter, and not so liable to crack as bells.

PROPORTIONS OF TALL CHIMNEY SHAFTS.—The following list, showing the rate of diminution and the proportion of base to height, in a number of large chimney shafts, may interest some of our readers. The figures are taken in some cases from the "Engineer's Pocket-Book" and similar works, and in other cases from the actual drawings of the shafts referred to. It is observable that the proportions of large chimneys vary considerably in different places. Local customs doubtless have their influence, but the special pur-

poses in view in each case have, and ought to have, more influence still. It makes a great difference whether the shaft is to be used for an engine boiler, an iron furnace, or a range of kilns, and a flue that would answer perfectly well for one of these, might do very badly for either of the others.

NAME.	Outside diameter at base.	Height above ground.	Diminution of width in 10 ft. of height.	Number of diameters high.
	ft. in.	ft.	in.	
Townsend's Chemical Works, Glasgow	62 00	454	4 3-4	14 1-5th, about
S. Rollox, Glasgow	40 6	432	7 1-4	10 5-8 "
Chemical Factory at Harmen, Prussia	18 00	331	2 1-4	18 1-3 "
Chimney at Bradford, Yorkshire	20 00	309	4 1-4	15 "
West Cumberland Iron Company, Workington (No. 1)	24 00	250	5	10 1-2 "
Dye Works, Hagen, Prussia	18 6	274	3 1-4	14 6-7 "
Pontifex's Works, Isle of Dogs	20 6	228	6	11 1-8 "
Shell Foundry, Woolwich	16 9	224	5 1-4	13 3-6 "
Messrs. Gostling's Northfleet (part fell)	22 00	220	6	10 "
West Cumberland Iron Company, Workington (No. 2)	25 00	240	5	8 2-3 "
Boring Mill, Woolwich	13 1	170	5 1-4	13 "
Rocket Buildings, Woolwich	11 6	154	7 1-4	13 "
Steam Engine at St. Ouen, France	10 8	132	5 1-2	12 "
Saw Mill, Woolwich	10 6	130	5 1-4	12 "
Paper Factory, Woolwich	10 3	120	5	11 3-4 "

THE SUTCLIFF GUN.—On the afternoon of Monday, the 3d instant, the new Sutcliff gun, weighing in its rough state 72,000 lbs., was successfully cast at the West Point Foundry, and, being the most gigantic piece of ordnance ever cast here, has created considerable interest.

At its last session, Congress made an appropriation for the purpose of assisting American inventors in their experiments on heavy artillery. Mr. Sutcliff, whose name the gun bears, is one of the few gentlemen whose plans are being tested by the Government. He is only interested in the steel mechanism which is to be attached to this "preacher that speaks to the purpose," as Miles Standish would call him.

The gun is made of the finest iron (standing a pull of 30,000 to 35,000 lbs.), and brought here by Messrs. Paulding, Kemble & Co., for this express purpose. The casting is now 19 ft. long, but when finished will be only 15. It will then have a steel barrel 4 in. thick at the breech and 3 at the muzzle, with rifle bore, and weigh 45,000 lbs. The ball will be 9 in. in diameter, and weigh about 250 lbs.

The mould was made a week ago, and at the time of casting was as hard as a sun-dried brick. It was so situated that the iron from two large furnaces could be run directly into it by means of troughs. The core is a cast-iron tube, wound with rope and covered with sand. This was filled with water the moment the metal was run in the mould. Twelve and a half minutes were occupied in casting, and the water, which was being forced through the core at the rate of 25 gallons per min., was raised from 38 to 51 deg. The core will be kept full of water 12 hours, when the iron will be sufficiently set to allow its removal. The water will then be exhausted, and as soon as the rope burns from its outside, tackling will be attached and the core withdrawn. Then Rodman's celebrated process will be kept up for six days. The bore being always full of water, of course the contraction from the inside goes on more rapidly than from without, and the desired strength is thus obtained. The portion next the water is first contracted by cooling; the part next cooled, contracts, and binds the first, as it were, like a band on the inside. The next layer acts similarly, and so on till all is cooled, each part successively binding that within till all is held with great tenacity. Eight days will be required to cool this monster, and at a cost of about $15,000.—*Iron Age.*

RIEHLE'S TESTING MACHINE.—Messrs. Reihle Bros., of the Philadelphia Scale and Testing Machine Works, have made some interesting tests of manilla rope, the results of which are important to many classes of our readers. The strength of the several sizes tested is shown as follows:

		Wt. lbs.
6	thread	625
9	"	950
12	"	1,375
15	"	1,800
18	"	2,250
1¼	inch.	2,750
1½	"	3 250
2	"	4,100
2¼	"	4,250
2½	"	4,750
2¾	"	7.375
3	"	8,000
3¼	"	9 750
3½	"	11,750
3¾	"	13,500
4	"	16,750

The above tests were made December 23, 1872, on one of Riehle Bros. patented "U. S. Standard Testing Machines," for Messrs. Edward H. Fitler & Co., Philadelphia, and can be relied upon as correct, as they were made very carefully, and upon the machine that tests were made for the United States Navy Department.—*Iron Age.*